THURSDAY, AUGUST 26, 1875

## *SCIENTIFIC WORTHIES*

### VI.—SIR CHARLES LYELL, BORN NOV. 14, 1797; DIED FEB. 22, 1875.

SINCE its last meeting the British Association has lost one of its oldest members and most illustrious presidents. There are some men the story of whose mental development and progress in scientific research may be taken as almost embracing the history, during their lives, of the science to which they devoted themselves. Of such men we have not many brighter examples than that of Sir Charles Lyell. For somewhere about half a century he continued in the van of English geologists, and so identified himself with them and their pursuits as to be justly taken as the leader of geological speculation in this country. The time has probably not yet come when his true position in the roll of scientific worthies can be definitely fixed The revolutions of thought which have taken place within the last fifteen years, and in which, let it never be forgotten, Lyell himself bore a conspicuous and indeed heroic part, have so shaken old beliefs which once seemed securely based on the most cautious induction from well-ascertained facts, that even they who have most closely watched the march of events will probably shrink most from the attempt to estimate the full and true value of the work of his long and honoured life. It is not, then, with any aim at such an estimate, but rather to recall some of the leading characters of his work, that this brief *in memoriam* is now written.

Perhaps the best idea of the solid services rendered by Lyell to Geology is obtained by looking back at the condition of the science when he first began to study it, and by contrasting that state with the same subject as treated by him in the early editions of his "Principles." To men who had been compelled to gain their general view of geology from such works as Daubuisson's "Traité," the appearance of Lyell's volumes must have been of the nature of a new revelation. From vague statements about early convulsions and a former higher intensity of all terrestrial energy, they were led back with rare sagacity and eloquence to the living, moving world around them, and taught to find there in actual progress now the analogues of all that they could discover to have been effected in the geological past. The key-note which Lyell struck at the very outset and which sounded through all the work of his career was, that in geology we must explain the past by the present;—that the forces now in operation are quite powerful enough to produce changes as stupendous as any which have taken place in former times, provided only that they get time enough for their task.

These views were not promulgated for the first time by the author of the "Principles of Geology." In cruder form they had been earnestly urged by Hutton, and eloquently illustrated and extended by Playfair. But after much turmoil and conflict of opinion, they had very generally been allowed to sink out of sight. On the Continent, indeed, they had never excited much attention, and were for the most part ignored as mere vague speculation. Even in this country they had only been partially adopted even by those who professed to belong to the Huttonian school. So that it was in one sense as a new doctrine that they were taken up by Lyell and enforced with a wealth of illustration and cogency of argument which rapidly gained acceptance for them in Britain, and eventually led to their development in every country where the science is cultivated.

In one important respect, however, the doctrines taught by Sir Charles Lyell differed from those of his predecessors. Hutton and Playfair knew almost nothing of fossil organic remains. They were necessarily ignorant of the light which these can cast upon the past history of the globe. They had but a dim perception of the long and varied succession of the stratified formations embraced by their own terms Primary and Secondary. After their days, however, the labours of William Smith among the Secondary rocks of England showed that the strata of the earth's crust could be identified and classified in their order of age by means of the fossil animal remains contained in them. Then came the brilliant discoveries of Cuvier in the Tertiary basin of Paris and the rise of the science of Palæontology. It was now seen that the discussion of theoretical questions in cosmogony and the collection and description of minerals and rocks did not comprise by any means the whole of geology. Year by year it became more evident that, besides all its records of physical revolutions, the crust of the earth contained materials for a history of organic nature from early geological times down to the present day. In this transition state of the science there was manifestly needed some leisured thinker who could devote a calm judgment and a facile pen to the task of codifying the scattered observations which had accumulated to so vast an extent, and of evolving from them the general principles which they seemed to establish, and which, when clearly announced, could not fail greatly to assist and stimulate the future progress of geology. Such was the task which Lyell set before himself, somewhere about half a century ago, and in fulfilment of which his "Principles" appeared.

In that great work the twofold aspect of geology—its inorganic or physical side and its organic or biological side—was recognised and admirably illustrated. It was in the treatment of the first of these that the earlier editions of the "Principles" stood specially distinguished from previous writings. The leading idea of their author was, as already remarked, not original on his part. Besides the writings of Hutton, Playfair, and their followers, the appeal to history and to everyday experience as to the true nature and results of the present working of the various terrestrial agents had already been made in considerable detail by Von Hoff in Germany. Nevertheless, until the advent of Lyell's work the views he adopted had got no real hold of men's minds. It was his enforcement of them which secured for them first a careful examination, and ultimately a very general acceptance. In explaining former revolutions of the globe, geologists had usually proceeded on the tacit assumption that no serious argument was required to prove these revolutions to have been far more violent in their progress and stupendous in their results than could possibly have been

achieved by any such energy as is still left upon the earth. Accordingly, on the whole they were disposed to neglect the consideration of proofs of modern changes on the earth's surface, looking upon these as mere faded relics of the power with which geological changes were formerly effected. It is impossible to exaggerate the service which Lyell did to the cause of truth by boldly striking at the very root of this fundamental postulate of his contemporaries, and showing, by a wide induction of facts from all parts of the world, how really potent were the present apparently quiet and ineffective processes of change. With most uncompromising logic he drove it home to the hearts and consciences even of sturdy convulsionists, that they had all along been reasoning in a circle, and that the evidence on which they so confidently relied demanded and could receive another and very different interpretation.

It was a great matter to shake the old convulsionist faith and bring men back to the study of the actual operations of nature at the present time. Greatly more difficult, however, was the task to build up another creed and gain adherents to it. Yet this was accomplished by Lyell with an abundant measure of success. He came to be recognised as the great reformer in geology, the high priest of the Uniformitarian school, the leader under whom in this country the younger men eagerly ranged themselves. Through the influence of his writings a fresh and healthy spirit of scrutiny and observation spread through the study of geology. And as edition after edition of his work appeared, each more richly laden than its predecessors with stores of facts gathered from all branches of science in illustration of his subject, men were led to realise how narrow had been the old conception which limited the scope of geology merely to the study of minerals and rocks and the elaboration of cosmological theories. Every department of nature which could throw light upon the terrestrial changes now in progress and thereby elucidate the history of those which had taken place in former times was made to yield its quota of evidence. Hence it came about that the study of geology received in Britain a breadth of treatment which had never before been given to it either in this or any other country. The main share in this reform must be assigned to the genius and perseverance of Lyell.

But in science as in politics no reform can provide for all the requirements of the future. In proportion to the zeal with which the new creed is adopted and proclaimed, there may be and often is an inability to recognise such measure of truth as may have underlain the older faiths, as well as to realise the weak points in that which is set up in their place. The essential doctrine of the Uniformitarian School was in reality based on an assumption not less than those of the older dogmas. It was an assumption indeed which did not rest on mere crude speculation, but on a wide range of observation and induction, and it claimed to be borne out by all that was known regarding the present economy of nature. It professed to be in accordance with the logical method of reasoning from the known to the unknown. Nevertheless, in the course of years the Uniformitarians gradually lost sight of the fact that the present order of nature on which they asserted that their system rested could not, without a manifest and perhaps in the end an unwarrantable assumption, be taken as the standard whereby the order of nature in all past geological time was to be gauged. The information gained by human observation during the few centuries in which man had taken intelligent interest in the world around him was valuable as a basis for hypothesis, but only for hypothesis which should be cast aside so soon as the requirements of a wider knowledge might demand. The Uniformitarians, however, gradually slid into the belief that though perchance they had not absolutely proved terrestrial energy never to have been more powerful than at present, yet they had shown that the supposed proofs of former greater intensity were illusory, and hence that their own doctrines should be accepted as by far the most reasonable, and indeed as the only safe guide in the interpretation of the past history of the earth. Most admirable has been the work done by the Uniformitarians, and deep are the obligations under which Geology must ever lie to them. But in the onward march of mental progress it is now their turn to have their confident belief called in question. Another School is rising among them, accepting from them by far the larger part of their doctrines, but in their own spirit of bold inquiry and with their own zeal in the cause of truth, seeking to enlarge the basis on which our ideas of the full sweep of nature's operations are to rest.

The other, or biological side of geological science, owes much of its development to the skill with which it was handled in the successive editions of the "Principles." Though not himself in the strict sense either a zoologist or botanist, Sir Charles Lyell throughout his life kept himself abreast of the progress of the biological sciences and on terms of intimate relationship with those by whom that progress was sustained in this country and abroad. He was in the true meaning of the word a naturalist. He had in his day few equals in the grasp which he could take of natural history subjects in their geological aspects. The geographical distribution of plants and animals was one of those subjects which received more and more ample treatment from him as he advanced in years. The succession of living forms in time was another theme which gave him full scope for accurate and eloquent description. In fact, the breadth of his conception of what geology ought to be was not less conspicuously marked in this than in the physical department of the science. He enlisted in his service every branch of biological inquiry which could elucidate the former history of the earth and its inhabitants. And not merely the published information on these questions, but many of the floating ideas of discoverers found exposition and illustration in his pages.

One of the biological subjects to which he devoted much time and thought was one which in recent years has received renewed attention and provoked increased discussion—the origin of the successive species of plants and animals which have appeared upon the earth. During the greater part of his career Sir Charles Lyell distinguished himself as one of the most uncompromising opponents of development theories such as those of Lamarck and the author of the "Vestiges of Creation." Such views ran counter to his uniformitarian faith, and he brought against them a large armoury of geological weapons. The non-appearance of higher

types of life among the older formations he contended to be no evidence in favour of development. It was simply negative evidence, and could at any moment be destroyed by the discovery of one positive fact in the shape of a bone, tooth, or other fragment. No one could make better use than he of such fortunate finds as that of Dr. Dawson among the ancient carboniferous forests of Nova Scotia, when from the heart of a fossil tree quite a little museum of land-snails and lizard-like forms was obtained; or those which revealed such remarkable assemblages of little marsupial and other mammalian forms from thin and local deposits like the Stonesfield slate and Purbeck beds. But negative evidence, when multiplied enormously by observers all over the world without any important contradiction, becomes too overwhelming to be explained away. Though convinced of the untenableness of the views of development which he opposed, Sir Charles may have had his misgivings at times that the yearly increasing and enormous body of negative evidence in favour of the non-existence of higher types of life in the earlier geological periods could not be due to the mere accident of non-preservation or non-discovery. At all events, when Mr. Darwin's views as to the origin of species were made known, Sir Charles, recognising in them the same basis of wide observation and the same methods of logical analysis for which he had himself all along contended in geology, at once and zealously accepted them—a bold and candid act, seeing that it involved the surrender of opinions which he had been defending all his life. In no respect did he show his remarkable receptive power and the freshness with which he had preserved his faculty of seeing the geological bearings of new truths more conspicuously than in the courage and skill with which he espoused Mr. Darwin's hypothesis and proceeded at once to link it with the general philosophy of geology.

Of his work among the Tertiary formations, with the nomenclature by which, through that work, they are now universally known, his observations on the rise of land in Sweden, his researches into the structure of volcanic cones, and other original contributions, over and above the solid additions to science supplied by the numerous editions of his popular works, it is not needful to make mention here. Enough is gained if at this time these few lines recall some of the services to which Sir Charles Lyell devoted a long, honourable, and illustrious life, which have graven his name in large letters on the front of the temple of science, and in memory of which that name will long be remembered with gratitude and enthusiasm as a watchword among the students of geology.

ARCHIBALD GEIKIE

## WATTS' DICTIONARY OF CHEMISTRY

*A Dictionary of Chemistry and the Allied Branches of other Sciences.* By Henry Watts, B.A., F.R.S., &c. Second Supplement. (Longmans, Green, and Co., 1875.)

THE appearance of the second supplement to Watts' "Dictionary of Chemistry" is an event in the history of chemical literature which will certainly be elcomed by all English chemists. Although it may be said with truth that no great generalisations have been made of late years in chemistry, the science is nevertheless advancing with gigantic strides so far as the accumulation of facts is concerned. Perhaps no science possesses such an extensive journalistic literature as Chemistry; month after month the journals of the Chemical Societies of London and Berlin, the *Gazzetta Chimica Italiana*, the *Annalen der Chemie*, *Poggendorff's Annalen*, the *Annales de Chemie*, the proceedings and transactions of the various learned Societies, as well as numerous smaller chemical publications, all contribute to the vast store of facts already recorded. It is not to be wondered, then, that during the nine years which Mr. Watts devoted to the compilation of his dictionary, the science should have continued its growth at such a pace that the author found it necessary to promise on the completion of the work (Preface to Vol. V., 1869) a supplementary volume bringing the record of discovery down to the existing state of knowledge. The first supplement accordingly appeared in 1872, bringing the history of the science down to the end of 1869. The volume now before us carries the record of discovery down to the end of 1872, and includes some of the more important discoveries made in 1873 and 1874.

From the contents of the present supplement we cannot select more than a few of the longer articles for notice here.

Turning first to the article on benzene, one cannot fail to be struck with the rapid growth of our knowledge of this body and its derivatives within the last few years. The list of haloid, nitro-haloid, &c., derivatives has been considerably increased since the publication of the last supplement by the discovery of new isomeric modifications of these bodies—modifications the discovery of which cannot but be regarded as signal triumphs to chemical theory when we call to mind the fact that the impetus given to the study of benzene, the fundamental hydrocarbon of the aromatic series, arose from the theoretical speculations of Kekulé and his school.

The subject of capillarity is treated of with considerable detail in an article some nine pages in length. The development of this subject is due to the researches of Quincke, Karmarsch, Buliginsky, Valson, and others. The article on chemical action contributes much of importance to the subject: we may particularly mention Mill's researches on the co-efficient of chemical activity, the numerous researches by Berthelot, in conjunction with Jungfleisch on the division of a body between two solvents, and with St. Martin on the state of salts in solution; likewise Favre and Valson's experiments on crystalline dissociation. Passing on to the cinchona alkaloids, we find that three new substances—quinamine, paricine, and paycine—have been added to the list by Hesse. The "constitution" of these cinchona alkaloids is among the problems still awaiting solution at the hands of chemists—may it not be hoped that the synthesis of quinine will one day—as that of alizarine—be a chemical possibility? In electricity, the chief additions to our knowledge are Becquerel's experiments on electro-capillary action, Quincke's theory of electrolysis, and Guthrie's experiments on the relationship between heat and electricity. The mechanical theory of gases has developed into a separate article of considerable importance in our eyes.

Avogadro's law—the safest foundation on which to build modern chemistry—is directly deducible from the fundamental equation of Clausius :—

$$p = \frac{nmc^2}{3v}$$

so that not only does our modern system of chemistry rest on a thermodynamical basis, but the future of chemical generalisation—judging from the tendency of recent research—lies in this direction also. The subject of heat has received great additions ; the laborious determinations of the specific heats of solutions by Thomsen furnish material for three pages. The "heat of chemical action" has developed enormously through the labours of Thomsen, Hautefeuille, Ditte, and Marignac. Berthelot has also contributed largely to the subject by his thermochemical researches. In industrial chemistry we find much valuable matter added to the metallurgy of iron, the article bringing us down to the invention of Siemens' rotative furnace for obtaining malleable iron and steel directly from the ore. In light, perhaps the most substantial additions to science are to be found in Gladstone's calculations of refraction equivalents, Christiansen, Kundt, Soret, and Sellmeier's researches on anomalous dispersion, and Rammelsberg's researches on the relations between circular polarisation and crystalline form. The articles on the chemical action of light and spectral analysis, contributed by Prof. Roscoe, are excellent *résumés* of the present state of knowledge in these branches of chemical physics. In the latter subject great progress has been made through the labours of Lockyer (discovery of long and short lines in metallic spectra), Roscoe and Schuster (new absorption spectra of potassium and sodium), and Lockyer and Roberts (new absorption spectra of various metals—suggestions for a possible quantitative spectrum analysis).

Prof. G. C. Foster contributes the article on magnetism, and Prof. Armstrong that on the phenols. Most of the articles on physiological chemistry are from the pen of Dr. H. Newell Martin ; and Mr. R. Warington furnishes some valuable articles on subjects relating to agricultural chemistry.

The second supplement exhibits all the care and painstaking conscientiousness of the former volumes, and will be found of invaluable service both to teachers and workers. The names of Mr. Watts and his coadjutors sufficiently guarantee the reliability of the work ; the "Dictionary" has in fact justly taken its rank as one of the standard works of reference in this country.

Seeing that the results of chemical research are flowing into the scientific world in a continuous and ever increasing polyglot stream, both professors and students of the science are indebted to Mr. Watts for the laborious task which he has accomplished for their benefit.

For our own part we look with eager interest upon the continuous encroachment of physics upon chemistry, and venture to hope that the time may not be far distant when generalisation may lead to natural classifications, causing the handbooks and dictionaries of the future to be for the same quantity of information somewhat less bulky in volume.

R. MELDOLA

## HIS ON MORPHOLOGICAL CAUSATION

*Unsere Körperform und das physiologische Problem ihrer Enstehung.* Briefe an einen befreundeten Naturforscher, von Wilhelm His. (Leipzig : Vogel, 1875. London : Williams and Norgate.)

THIS is not, as might perhaps (from its title and from a hasty glance at its contents) be imagined, a popular exposition of the main facts of Embryology as ordinarily understood. Prof. His has been led by his researches to adopt peculiar views concerning the causation of animal forms. These he has explained at some considerable length in his great work on the "Development of the Chick," and elsewhere, but they have not met with very general acceptance ; and the little work we are noticing has for its object a popular and somewhat fuller explanation of these views, and a defence of them against various critics. Among these critics the most conspicuous is Haeckel, whose, to say the least, severe remarks on the author have occasioned a very spirited retaliation. In fact the work, small as it is and popular as it is intended to be, is very largely controversial ; and it has always appeared to us a sign of weakness when a scientific combatant brings his quarrel before a general public.

Without going at all fully into the views of our author, we may say that he strives to explain many of the facts of animal morphology by the agency of mechanical causes acting directly on the growing germ or embryo. Thus, for him the large eyes of the young chick are the direct cause, by compression, of the sharp beak of the bird ; and more generally the unequal tensions produced by unequal growth in the initial flat blastoderm determine, through the agency of certain folds, the form of the animal which springs from it.

As might be expected, many pages of the book are devoted to an attempt at reconciling these views with a modified theory of descent. Speaking broadly, the views of the author may be said to differ from those generally entertained, chiefly on the question whether it is the horse which pulls the cart or the cart the horse, or perhaps rather on the point which is the cart and which the horse. We very much fear that Prof. His's horse is really the cart.

M. F.

## OUR BOOK SHELF

*Bristol and its Environs, Historical and Descriptive.* Published under the sanction of the Local Executive Committee of the British Association. (London: Houlston and Sons. Bristol : Wright and Co., 1875.)

IT was some time ago announced that a Guide to Bristol was being prepared for visitors to the British Association Meeting. This is now published, and appears as an 8vo volume of 475 pages bound in cloth. In many respects the local committee have made great exertions to make the visit in every way a pleasant one, and this has been pretty well known, but so voluminous a guide as this is certainly a surprise. It is well got up, and is illustrated both with views of the buildings in the town and with diagrams illustrative of the geology of the district. Many pens have been employed in its preparation. "The contributions," the Introduction states, "are honorary—the several authors have written with pure love of their subject, and for the sake of doing homage to the occasion that has called forth the volume."

The first two sections, both of them on Ancient Bristol, are by Mr. J. Taylor, of the Bristol Library. Section 3, on Modern Bristol, is by Mr. J. F. Nicholls, of the City Library. The fourth section, on Local Government and Taxation, is by Mr. H. Naish: and then follows a section on Educational Organisations, to which there are several contributors. Mr. D. Davies, the medical officer of health, has supplied the section on Sanitary Condition and Arrangements, after which comes Section 7, on Physical Geography and Geology. This occupies sixty-four pages, and would perhaps have been of more practical use if printed as a separate pamphlet that could be conveniently carried in the pocket. Mr. Tawney has written the Introduction; the Silurian, the Carboniferous, and Millstone Grit is by Mr. Stoddart; the part on the Coal Measures and "New Red Period" is written by Mr. Tawney; that on the Rhætic and Liassic by Mr. Ralph Tate, and the concluding part on the Inferior Oolite is again by Mr. Tawney.

Bristol is better off for geological maps than any other part of the country, for not only are there the sheets of the Geological Survey, but there is Mr. Sanders' splendid map of six inches to the mile, which includes the whole of the Bristol coal-field.

It is a pity there was not a sketch map introduced in the guide, with just the names given of the places referred to and an indication of the spots where the sections are taken from. As it is, strangers to the district will experience some difficulty in following the text, as many of the names are not on the published maps. With regard to the sections, too, there is no indication of the direction in which they are taken, nor of the scale to which they are drawn. One of the most useful features of the geological portion is that which gives the localities where the sections of the strata can be seen; and, as the district within a short distance contains from the Silurian up to the Oolites, omitting the Permian, is of interest. There are many references to the more important papers that have been printed, and in cases of difference of opinion the writer has added his own views. The much vexed question of the age of the "dolomitic," "triassic," "magnesian," or "reptilian" conglomerate, is duly referred to.

The notes on anthropology have reference to the tumuli and chambered barrows, and to the present condition of Bristolians. "A certain amount of physical degeneration has taken place among the native Bristolians, as among the natives of other British cities; 300 of them yielded to me an average stature and weight of 5 feet 5·8 inches and 132½ lbs., after deductions made for shoes and clothing. The average height of men in the surrounding counties may fairly be put at half an inch more."

The book has one serious defect, for which the compiler and not the authors are responsible; there is no index.

## LETTERS TO THE EDITOR

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, or to correspond with the writers of, rejected manuscripts. No notice is taken of anonymous communications.*]

### "Climate and Time"

THE review of "Climate and Time" in NATURE, vol. xii. p. 121, contains some remarks in reference to my tables of the eccentricity of the earth's orbit, to which, in justice to myself, I must refer, the more so as they relate to points which comparatively few of your readers have it within their power to determine whether or not the reviewer was justified in making the rema rks in question.

"We have repeated," says the reviewer, "the calculations for two of the most remarkable dates, viz., 850,000 and 900,000 years ago respectively, and find that at the former date the eccentricity was ·0697 instead of ·0747, and at the latter date was ·0278 instead of ·0102 as expressed in the table."

What proof does the reviewer give that his results are correc and mine incorrect? The following is the reason he assigns:—"To satisfy ourselves," he says, "that the mistakes are Mr. Croll's and not ours, we have recalculated also one of Mr. Stone's and one of M. Leverrier's, and in both instances have exactly verified them." This can hardly be accepted as sufficient evidence, for I had myself recalculated one of Mr. Stone's and no fewer than five of M. Leverrier's, "and exactly verified them."

I suspect that the reviewer has made his calculations somewhat too hastily; for if he will go over them a little more carefully, he will, I have no doubt, find that after all my results are perfectly correct, excepting only a trifling typographical error, to which I shall presently refer.

The value for 900,000 years ago ought to be ·0109 instead of ·0102, as stated in the table. This mistake arose out of the curious circumstance of a small speck of ink having been dropped on the tail of the 9, which led to its having been substituted for a 2, ten years ago when the tables were first published—a fact of which I was not aware till a week or two ago, when looking over the manuscripts of my original calculations, all of which I have preserved. Since my calculations were called in question by your reviewer, I have had them examined by three experienced mathematicians, and the conclusion at which each of them has arrived is that they are perfectly correct.

The reviewer continues:—"The fact that the eccentricity was large when he represents it so, and small when he makes it small, seems to indicate that some approximating progress [process?] has been followed, and that possibly his diagram may give a *rough* idea of the changes of eccentricity for past time."

I can assure the reviewer that nothing could be further from the truth than this assumption. I have computed the eccentricity and longitude of the perihelion for no fewer than 129 separate periods, and in every case Leverrier's formulæ have been rigidly followed, and I have every reason to believe that the diagram gives not a *rough* but an *accurate* idea of the changes of eccentricity. The values given in the tables will, I trust, be found to be perfectly accurate up to at least the fourth place of decimals, which is as far as these formulæ can be relied upon to yield correct results.

The following are the results which, considering the trouble that has been given to their verification, I think will stand the most severe scrutiny:—

| Period 850,000 years ago. | Period 900,000 years ago. |
|---|---|
| $h^2 = \cdot 00413927$ | $h^2 = \cdot 000059858$ |
| $l^2 = \cdot 00144124$ | $l^2 = \cdot 000059812$ |
| $h^2 + l^2 = \cdot 00558051$ | $h^2 + l^2 = \cdot 000119670$ |
| $\sqrt{h^2 + l^2} = \cdot 0747 =$ Eccentricity | $\sqrt{h^2 + l^2} = \cdot 010939 =$ Eccentricity |

Edinburgh, August 10 JAMES CROLL

### A Lunar Rainbow, or an Intra-lunar convergence of Streams of slightly illuminated Cosmic Dust?

ABOUT 8.30 P.M. yesterday a large zone of the sky, from the horizon at W.N.W. to the horizon at E. by S., was illuminated in a very remarkable manner, and this illumination lasted about three-quarters of an hour, when it gradually died out.

During all this time the sky was very clear and cloudless, thereby forming a dark back-ground, on which the phenomenon, whether lunar rainbow, or many rainbows, or intra-lunar converging streams of cosmic matter, was splendidly projected.

This exhibition consisted of one grand central feather springing out of the horizon at W.N.W. and crossing this meridian at about 20° north of the zenith. The width of this stream, with little variation throughout its length, was 7° or 8°. Its light was that of a *very bright* white cloud, its edges most beautifully defined; its form that of a very elongated feather, but without any shaft. On either side of this main feather was a system of seven or eight minor and fainter streams, threads, or beams of light, all more or less extending from the western to the eastern horizon, subtending a chord common to themselves and to the main stream of light, and converging towards the axis of the central stream so as apparently to intersect it at a point about 30° or 40° below the western horizon, at which the whole system subtended an azimuth of about 20°; and near the zenith, where its transverse section was a maximum, that section subtended an angle of about 40°. At this time the moon was about 15° east of the meridian, and her declination about 9° S. Both systems of the minor streams of light on the sides of the main stream appeared to have a slight

libratory motion, or to slew upwards towards the main stream, and therefore perpendicularly to their length.

Nothing could suggest to the mind more strongly the idea of converging streams of infinitely minute particles of matter passing through space at a distance from the earth less than that of the moon, and at which the earth's aërial envelope may still have a density sufficient, by its resistance, to give to cosmic dust passing through it with planetary velocity that slight illumination which i tpossessed.

The rapid development of the luminosity of these streams on this occasion is evidenced by the fact that they were observed at the time of leaving church, namely, 8 P.M. to 8.20 P.M., by none of the several congregations of this town and Perth, but were observed by many persons from a quarter to half an hour after that time, so far as I have yet been able to ascertain by a rather extensive inquiry. On coming out of church I myself certainly looked round the whole visible horizon and the higher portion of the heavens, and I made to a companion some observations on the clearness of the stars and dark blue colour of the sky; but about twenty minutes after my exit from church these streams of light had attained their maximum of illumination.

Their apparent figure was that of a nearly circular (slightly flattened) arc of an amplitude of 15° or 20°, as viewed from the middle point of its chord. Both the brightness and the convergence of the streams towards the western horizon were more marked than those towards the eastern horizon.

Fremantle, West Australia, May 17 J. W. N. LEFROY

PS.—Since writing the above, in the Supplement of the *South Australian Register* of Thursday, May 20, I have found the following paragraph:—

"A beautiful lunar rainbow was visible in the western heavens on the evening of Sunday, the 16th inst., a few minutes after 8 o'clock. For a short time the arch was nearly perfect, but for upwards of fifteen minutes the limbs were very bright. The southern limb also appeared visible for some time after the upper portion of the arch had faded away."

Now, allowing for the difference of local time between Fremantle and Adelaide, I think it fairly assumable that this paragraph must refer to the same phenomenon which I have attempted to describe as above; and, if so, it clearly shows that it was *not* a lunar rainbow. I can find no allusion to it in any Melbourne paper yet received here, and which reach to the 19th inst. There the sky may that evening have been cloudy, and thus have rendered it invisible. All intelligent persons here who observed it, and with whom I have had opportunity of conversing since the 16th inst. to this day, concur in my impression that minor lateral streams or feathers of light on the north side of the main stream intervened between the earth and the moon, and one or more of them in its slow librations swept the surface of the moon and sensibly obscured its light.—J. W. N. L.

May 31

### "Instinct" and "Reason"

A FEW facts came under my observation during the spring of this year that strikingly illustrate this subject. A pair of blackbirds built a nest on the top of my garden wall, which is thickly covered with ivy and within three yards of the drawing-room window. When the young birds were about three parts fledged one of them by some mishap left the nest and fell into the flower garden. My cat (seven years old, and which has killed scores of small birds) immediately found it, and at the same time a kitten (about three months old, but not belonging to the cat) began to pay rather rude attentions to the young blackbird, and would have used it as kittens are wont, but the old cat would not suffer her to touch it. The cause of this was the old cock blackbird, being aware of the peril of its young, made a great noise and kept flying here and there around the scene of action, crying and scolding with might and main. It then became evident to me that the cat had two or three objects in view, and a purpose to gain. Firstly, not to allow the kitten to touch, or kill, or make off with the young bird. Secondly, to use the young bird as a decoy to entrap the old one. Thirdly, to make the young bird cry sufficiently from fear or pain to induce the parent's affection to overcome its discretion.

During the manœuvres old Tom repeatedly made unsuccessful springs to catch the cock-bird, alternately running to give the kitten a lesson of patience, or self-denial, or impose a fear of punishment. The young bird repeatedly hopped out of sight amongst the flowers and stinted its cries; then anon the cat touched it again and made it flutter about and cry again, which from time to time brought the old bird down with cries of terror, or wrath, or a blending of both emotions, and almost into the very mouth of the cat. Two or three times I thought old Tom was successful, but no, he missed his object most surprisingly. It became evident to me that the cat was using the young bird as a decoy to catch the old one. After I had watched some ten or fifteen minutes, it became too painful for me to witness, so I caught the young bird and put it again into its nest, which was about ten feet from the ground.

In less than an hour the young bird was again on the ground, the cat, kitten, and parent bird performing the same drama, with this difference in the acting: the cat lay down, rolled about, or sat at a convenient distance from the young bird, yet with eyes alert, though half shut, and otherwise giving an assurance that he did not intend to make another bound without succeeding to catch his prey. He was, however, disappointed, and made four without achieving his purpose. At this juncture the mother-bird came on the stage with cries of distress, but kept aloof on the branches of a tall cherry-tree that rises above the wall; and if her boldness were less than the cock-birds's, her discretion was greater, for she kept far aloft. Once it seemed to me that the cock-bird actually struck the back or head of the cat with his wing and mandible. This scene continued about seven or ten minutes, when I again caught the young bird and threw it over the wall, and the exhibition of animal thought, emotion, and passion ceased.

Here were manifested phenomena of a more remarkable kind than those seen in the cases cited by the Duke of Argyll in the *Contemporary Review* for July, in an article to illustrate "Animal Instinct in relation to the Mind of Man," for the cat showed an amount of reasoning which he probably never before exercised, because never before placed in the same circumstances. That he had used young sparrows, of which he must have caught scores, as decoys to catch the old ones is possible, but I am perfectly sure that no kitten ever was in the garden during his reign as "monarch of all he surveyed" in the shape of birds. Hence his authority over the kitten, which was full of life and eagerness to appropriate the young bird, the killing of which would have defeated the purpose of the cat in using the young bird as a decoy to catch the old one, was indeed remarkable, and disclosed a combination of mental forces of self-conscious reason of no trifling order, and, as it appears to me, conclusive that the difference—and only difference—between instinct and reason is one of degree. JAMES HUTCHINGS

Banbury, Aug. 16

## OUR ASTRONOMICAL COLUMN

DOUBLE STARS.—Dr. Doberck, of Markree Observatory, has published a first approximation to the elements of $\zeta$ Aquarii, on measures between 1781 and 1870, in which long interval, however, the angle of position has only changed 45°—a case where very great latitude must be allowed to any orbit that may be deduced. Dr. Doberck fixes the peri-astron passage to 1924·15, and assigns a period of revolution of upwards of 1,500 years. The latest measures we have met with are those of Nobile, taken at the Observatory of Naples in November 1873, giving the angle 335°·5, or 3°·4 greater than that calculated.—There appears now a probability that the smaller component of 44 Bootis has passed its greatest apparent distance from the primary several years since: if good measures of distance have been made this year, they ought to be sufficient to enable us to pronounce definitely upon this point. That this star forms a true binary there can be no doubt, though it is Sir W. Herschel's measures in 1781 and 1802 alone, that afford conclusive evidence of the physical connection of the components. Thus we might represent the measures between Struve's earliest in 1819 and the present time by the formulæ

$$\Delta\, \alpha = -\, 3''\cdot 4233 - [8\cdot 8968]\,(t - 1830\cdot 88)$$
$$\Delta\, \delta = -\, 1\cdot 6979 - [8\cdot 3115]\,(t - 1830\cdot 88)$$

But if we calculate from the same formulæ for Sir W. Herschel's epochs we find,

| | | | | |
|---|---|---|---|---|
| 1781·62 | Position | 156°·1 | Distance | 0''·75 |
| 1802·25 | ,, | 214·8 | ,, | 1·35 |

These are greatly at variance with the positions observed, which show that the companion was then in the following semi-circle, and by the estimates of distance had approached the primary between 1781 and 1802. Barclay's epoch 1871·4 assigns a distance less by 0″·35 than was observed at Leyton in 1866, which is confirmed by Dembowski's measures about the same time. There is in the case of this star a very unusual discordance between the distances of Struve and Dawes, which attains a maximum, 0″·45, about 1836·5; in deducing the above formulæ Struve's measures were employed. The rate of increase in the distance has been diminishing, until by Dembowski's measures, 1863-68, it was less than 0″·01 annually; the orbit is evidently inclined only a few degrees to the line of sight, so that the companion made a very close approach between 1802 and 1819.—If the angles of position, in the case of Σ 1819 between 1828 and 1870 are projected, it will appear that the velocity has been diminishing from about 2°·1 in 1840, to 0°·85 at the end of the period, which with the accompanying increase of distance confirms Struve's judgment as to orbital motion; there is already a diminution of angle of nearly 70° since the first Dorpat measures.—It may be hoped that Σ 2107 has not been forgotten this year.

M. LEVERRIER'S THEORY AND TABLES OF SATURN.—We learn that M. Leverrier has completed his long-continued and exhaustive investigations on the motion of Saturn, and that his theory is reduced into tables, which will of course speedily take the place of those of Bouvard, or of provisional tables which have been used in the preparation of one or two of our ephemerides, pending the publication of others founded upon a more complete theory and discussion of the observations from the time of Bradley. As in all Leverrier's previous researches of a similar nature, he has made use of the rich store of observations accumulated at the Royal Observatory, Greenwich during upwards of 120 years, and also of the long series which has been formed at the Observatory of Paris. The mathematical astronomer will await the publication of M. Leverrier's researches in detail with extreme interest. The Tables of Saturn are understood to be necessarily of considerable extent, with the view to their convenient application.

THE GREAT COMET OF 1819.—The parabolic orbits so far computed for this comet, which was observed from the beginning of July to the middle of October, do not represent the observations with sufficient precision, and it is probable that no parabola will be found to do so. The following may, perhaps, be closer than any yet published:—

| | | |
|---|---|---|
| Perihelion passage 1819, June | 27·71547, | Greenwich M. T. |
| Longitude of perihelion ... | 287° 8′ 11″ | Mean equinox July 0 |
| Ascending node | 273 41 57 | |
| Inclination ... | 80 44 38 | |
| Log. perihelion distance ... | 9·533233 | |
| Heliocentric motion ... ... | direct. | |

But this orbit exhibits differences from the observations of a kind that should probably be attributed to deviation from parabolic motion, and as we are in possession of many of the original observations, it would be desirable to discuss them with the view of determining the true character of the orbit in which the comet was moving. Its transit over the sun's disc, a nearly central transit, early on the morning of June 26, and the suspicion that it was actually observed upon the disc by Pastorff at Buchholz, or, as is even more probable, by Stark at Augsburg, give it a peculiar interest. The diagram of the comet's path across the sun, which appears in the "Berliner Astronomisches Jahrbuch," is erroneous; it would pass in greater longitude than that of the sun's centre, as indicated by the above elements, which in this respect are confirmed by the orbits of Nicolai, Dirksen, and Cacciatore. For the centre of the earth the ingress took place June 25 at 16h. 52m·9 mean time at Greenwich, 172° from the sun's north point towards the east (direct image), and the egress at 20h. 29m·9, about 9° from the same point to the east. For the time of transit the elements, no doubt, assign the comet's position within 15″ or 20″. The larger differences from observation are in August.

## SCIENCE IN GERMANY

(*From a German Correspondent.*)

IN continuation of the previously reported investigations of the formation of cells in the ovum, we may mention some observations of Kupffer, which relate to a hitherto rather unknown yet doubtless very widely spread structure of the animal cell. ("On the differentiation of protoplasm in the cells of animal tissues," from "Schriften des naturwissenschaftlichen Vereins für Schleswig Holstein," Heft. iii.; and "The salivary glands of *Periplaneta orientalis* and its nervous system," from "Beiträge zur Anatomie und Physiologie, als Festgabe Carl Ludwig zum 15 Oct. 1874, gewidmet von seinen Schülern.") Kupffer first discovered that the body of the cells from the liver of a frog, which coat the biliary vessels, consists of two substances which chemically and physically are widely different, while hitherto it had been considered homogeneous throughout and had been called protoplasm. A hyaline ground substance (Paraplasm) gives to the body of the cell its relatively firm exterior shape, while in its interior a moveable, grained protoplasm is found in varying arrangement. It appears as a central mass round the nucleus, from which ramified or reticular threads radiate to the exterior side of the liver-cells which is turned towards the blood-vessels, or to that which borders the biliary vessels. From this arrangement of the protoplasm, which slowly flows in the well-known manner, Kupffer surmised that these were the ways in which certain matters were conveyed from the blood into the biliary vessels; and he found his opinion confirmed when he introduced soluble colouring matter into the blood of the living animals. As the colour entered through the liver-cells into the biliary vessels, it indicated its course through the cells in most cases in exactly the same way in which formerly the protoplasm proper had been found arranged. Similar facts were found in respect to the liver and kidneys of other Vertebrata, in the young back-teeth of calves, in certain glands of insects (Malpighian bodies). In the salivary glands of the well-known "black beetle" (*Periplaneta*), Kupffer not only found a very soft net of protoplasm-threads inside the ground-substance of the cells, but he also proved their connection with nerve ends. This likewise supports the view that the substance of the animal cell is differentiated in a manner similar to that of the vegetable cell, viz., that it consists of an active material which remains moveable and fulfils the special physiological functions of the single cell (protoplasm), and of a more passive material which forms a sort of protecting receptacle, as it were, for the tender protoplasm (Kupffer's paraplasm).

The "Archiv für mikroskopische Anatomie," edited by La Valette St. George and Waldeyer, has produced the following papers in its eleventh volume, up to this date:—Part I. On Radiolaria and fresh-water Radiolaria-Rhizopoda, by Greeff.—On bone growth, by Strelzow.—Researches on the physiology of the kidneys, by Wittich.—Studies on Rhizopoda, by F. E. Schulze.—Researches on the ganglion globules of the spinal ganglia, by Arndt.—On Heitzmann's hæmatoblasts, by Neumann.—On tissue cells by Waldeyer. Part II. The Ventriculus terminalis of the spinal marrow, by Krause.—Remarks on the nerves of dura mater, by Alexander.—Studies on the development of bones and of bone-tissue, by Stieda.—On the peripherical part of vertebræ, by Ehrlich.—The perivascular lymph-spaces in the central nervous system, and in the retina, by Riedel.—On cement layers in the tissues

of vessels, by Adam-Kiewicz.—Hyalonema Siebold, Gray, by Küstermann.—Researches on the development of spermatozoa, by Neumann.—On amœboid motions of the little nucleus-body, by Eimer. Part III. Studies on Rhizopoda, by F. E. Schulze.—The relation of ciliated epithelium of the abdominal cavity to the epithelium of the ovary, by Neumann.—Researches on the first signs of the eye-lens, by Mihalkowics.—Vertebral side and cerebral appendage, by the same.—Researches on the development of cross-striped muscles and nerves of Reptilia and Amphibia, by Calberla.—On the reproduction of Arcella vulgaris, by Bütschli.—Researches on the epithelium of the nose, by Brunn.—On the nerves of the gullet, by Goniaew.—Researches on the anatomy of the human throat, by Disse.—On the structure of the Najadeuxieme, by Posner.—Supplement: On the dental system of Reptilia, and its significance with regard to the genesis of the skeleton of the oral cavity, by O. Hertwig.—The above-mentioned researches of Greeff and Schulze, which are in close relation with those made in England by Archer and Carter, treat of a class of the lower animals which only lately has attracted great attention; we therefore can hardly be astonished that in such treatises, descriptions and determinations of the different forms are in the majority, and that the particular course of life of single species remains at present still wrapped in considerable darkness. These neat little organisms consist of a very simple substance, which supports their existence (sarcode) and of a siliceous skeleton, which in some instances radiates outwardly in all directions, while in others it appears as a bag- or bottle-shaped shell, and is often adorned with relief-work well worthy of admiration. As indications seem to become more and more numerous that not only within the range of one species, but even in the development of one and the same individual animal, different forms occur, it is evident that the propagation and development of these organisms must remain difficult to understand, so long as these relative connections are not investigated. But thus much is already known, that even in the most distant localities the same forms may occur, and that the marine Radiolaria and Rhizopoda have near relations, or even identical forms, in fresh water. Besides division, the following phenomena seem to be connected with propagation: the phenomenon of conjugation (temporary union of two animals), of "encystifaction" (enclosing by a shell of the animal which is contracted into the shape of a ball), and of the formation of spores (production of interior germs, according to Bütschli).

## *ZOOLOGICAL STATIONS ABROAD*

THE following letters from Dr. Mikluho-Maclay to Dr. Anton Dohrn, Director of the Zoological Station at Naples, have been forwarded to us for publication by Prof. Huxley. The first relates to a zoological station which Dr. Maclay has established in the Malay Archipelago, and the second to the general subject of zoological stations abroad.

"Dear Dohrn,—You are well aware that I share your views as to the great value of zoological stations to science, and you will not doubt that the account of the excellent results of the great establishment founded by you at Naples, which reached me by accident at Ternate in 1873 on my return from my first expedition to New Guinea, gave me great pleasure.

"It is now my turn to surprise you with the news of the establishment of a third (?)[1] *zoological station at the southernmost point of Asia*, on 'Selat-Tebrau,' the strait which divides the island of Singapore from the Malay Peninsula.

"This new 'station' cannot, it is true, be so called in the same sense as yours at Naples. I have taken my own requirements and customary mode of life as the standard, and have arranged the building and its fittings in accordance with it.

"It will serve in the first place as a station and *Tampat Senang* (or place of rest) for *myself;* in my absence, and after my death, I wish to place it at the disposal of any student of nature who feels himself suited for my mode of life.

"My 'Tampat Senang' has the following advantages to offer:—

"A house consisting of two fairly large rooms, each provided with two verandahs (besides the necessary offices), surrounded on three sides by the waters of the straits, and on the fourth by the primeval forest.

"The house will be simply furnished, and will contain a small library, together with the most necessary articles for housekeeping.

"It possesses, moreover, two advantages which I consider to be of no small importance, namely, the command of a fine view, and very complete isolation.

"The use of this 'Tampat Senang' is open to *any* student of nature, without the slightest regard to nationality, provided only he be of the male sex (for I confess to a decided repugnance to all stages of development and differentiation of the genus 'blue stocking.') The presence of a woman as visitor, or as supplement of the one student of nature for whom the place affords room—for in this case a wife must be so regarded—is not forbidden; but since 'Tampat Senang' must remain true to its name and to my idea, no children can possibly be allowed there.

"I have purchased the piece of land on which the house is to stand, from H.H. the Maharajah of Johore. It is a small hill which forms a cape projecting into the Selat Tebrau. In my will I have made such provisions that my family, into whose hands it will pass, will be precluded from *ever* selling it, or allowing it to be used for *any other* purpose than as a station for scientific research; or from cutting down, or even thinning the primeval woods standing upon it; the utmost that will be allowed is the clearance of one or two footpaths through the wood, which is always to remain as a specimen of the untouched primeval forest. And although 'Tampat Senang' may be hereafter rebuilt in stone, and made more elegant or convenient, it is *never* to be enlarged, lest it should lose its character of an isolated abode for *one* student of nature.

"I lose no time in writing to you, although the ground is only just purchased and the house is not yet built, because I think the plan of establishing such outposts for students of nature in these parts of the world (the East Indian Archipelago, Australia, the islands in the Pacific Ocean, Japan, &c., &c.) likely to be *very useful*, and also because, on account of my present ailment (an injured foot), I have more leisure than usual.

"Hotels can never afford suitable places of study on account of the noise and confusion inseparable from them; nor can the hospitality of friends, however kindly it may be offered, supply all that the student of nature needs. Such unpretending stations as my future 'Tampat Senang,' where he can work in absolute quiet, neither disturbing others, nor suffering interruptions, without the need of asking favours or incurring obligations, will I think commend themselves to many persons interested in the advancement of science.

"A principal reason for my choice of Johore is the neighbourhood of Singapore, from which place 'Tampat Senang' can be reached in three or four hours. The advantages of this position are that all products of European industry can be easily procured; that by means of the frequent mails communication can be maintained with

[1] I have not heard whether the station which you and I began at Messina in 1867-68 arrived at any high degree of development, or whether it shrank into a mere rudiment. My nomad life has prevented news of any other than yours at Naples from reaching me; for example, I do not know whether the station on the Black Sea, which I advocated at the meeting of Russian naturalists at Moscow in 1868, ever came into existence.

all parts of the world; that very fair libraries are accessible at Singapore and Batavia; and that, at the latter place, scientific papers can be published in French, German, or Dutch, in the *Natuurkundig Tijdschrift*, while the *Journal of Eastern Asia*, of Singapore, publishes similar works in English.

"In the hope that you may be one of those who will make use of my 'Tampat Senang,' I remain, with all respect and friendship, "N. N. MIKLUHO-MACLAY

"28th April, 1875, Istana Johore,

"Residence of H.H. the Maharajah of Johore."

"In life, as in everything else, it is important to distinguish main points from secondary matter, and to act accordingly. Main points always remain main points, however important secondary objects may sometimes be. On account of this evidently correct view, I continue my journey into the interior of the Malayian peninsula, as my health is improving; to-morrow I shall go to Pahang, and for the moment I give up building the 'Tampat Senang.' It is possible that I must try and find some other locality than Johore for this, because the Maharajah of Johore, after nearly two months' talking, in which time I had made out all the plans and had completely gone through all the details of the proposed building, has at last declared to me that he only could let me have that tract of land which I had chosen for the 'Tampat Senang' for a certain number of years, and that he must retain certain rights on the same. As all this does not agree with my plans, and as the locality is not of decisive importance, I shall, in case the Maharajah does not decide differently, construct my 'Tampat Senang' somewhere else.

"I consider the foundation of Zoological Stations in the tropics (however simply and poorly they may be fitted out, if they are otherwise quiet and comfortable places for work) as of the greatest importance for zoology and botany, since museum collections and preparations in spirits cannot afford sufficient material for investigation either with regard to quantity or quality.

"I have sent a proposal to the Society of Naturalists at Batavia, to found a 'Tampat Senang'[1] for naturalists in the Moluccas (at Amboina or at Ternate), and I intend to send similar proposals to scientific societies at Calcutta, and in Australia, and to some friends in Chile. If Russian Societies of Naturalists assist me I intend eventually to found a Zoological Station at the Sea of Ochotsk, or on the Pacific Ocean, myself.

"Zoological Stations in the Moluccas, in the Himalayan Mountains, in Tasmania, in the Fiji Islands, in Magellan's Straits, in Kamtschatka, &c., will yield not a few important results for all natural sciences. These stations will be particularly important for those naturalists who travel not only as tourists or as trade travellers of science, as it were, but who are engaged on some special work which requires large and fresh materials. Upon my return (which, however, is very uncertain at present) I will communicate to you my plans on the 'Tampat Senang' (the name seems to me to be quite appropriate) in detail. As it seems to me, they must be somewhat different from such Zoological Stations as your own at Naples, or we shall have to wait too long for their foundation. On my part I shall do all in my power for the carrying out of this idea, which nevertheless must remain a secondary (although important) object for *myself*.

"The day before yesterday I read in NATURE of May 6 of the official inauguration of your station at Naples, with much pleasure, and amongst the names I found those of several friends and acquaintances; so that I am led to hope that the scientific world will be interested in the 'Tampat Senang' in other parts of the globe.

[1] It is a matter of course that what I expect from my future "Tampat Senang" cannot apply to others. Only mine shall remain true to its name, whether built at Johore, or at the Maclay coast in New Guinea.

"My kindest regards to yourself and all workers at the Zoological Station of Naples.

"N. N. MIKLUHO-MACLAY

"Istana, Johore, 9th May (June?) 1875"

## THE VATNA JÖKULL, ICELAND

THE following letter from Mr. W. L. Watts in reference to his journey across the Vatna Jökull has been forwarded to us by Mr. Logan Lobley. As we noted last week, this is the first time the Vatna Jökull has been crossed. The letter is dated "Grierestadir, by Jökull sá á fjöllum (Iceland), July 12, 1875."

"I am happy to say I have crossed the Vatna Jökull. It occupied between fifteen and sixteen days in bad weather. Euriffa is by no means the highest mountain in Iceland; my aneroids registered 1,250 feet above Euriffa's height, subject to their correction upon my return to England.

"I feel certain that the Jökulls of Iceland are advancing at a considerable speed. The part of the Vatua Jökull, in the south of Iceland, called Breithamerker Jökull, has advanced about one mile and a half since the 10th of May last, and threatens to cut off all communication in that direction along the shore. I think, however, its rapid advance is not, as the natives believe, owing to volcanic heat in the Vatna Jökull, but that it is caused simply by the vast increase of frozen material upon its cloud and storm-wrapped heights. This accumulation above the height of 5,000 feet goes on both in summer and winter, and below for another thousand feet the waste during the summer months by no means equals the accumulation during the rest of the year. The glacier at the north point, at which descended, by Kistufell has advanced about twelve miles since the making of Olsen's map of 1844, diverting the course of the Jökull sá á fjöllum and causing it to rise about twelve miles from where it appears to dó upon the map, *i.e.* about eleven miles N.E. of Kistufell and twelve NN.W. of Kverker Jökull, instead of at the base of Kistufell. The grand old water-course it has vacated forms an excellent road for several miles. I feel sure Iceland must slowly but surely in course of time succumb to the same fate as befell the Greenland colonies.

"I am now about to proceed to the active volcanoes upon the north of Vatna Jökull. They are situated in the part of the Odalters-braun called Dyngurfjöllum, and as I expect in the Kverker Jökull. I shall have no time to hunt for any more this year, but if time will allow I shall visit the source of the great lava stream of Skaptar Jökull, a mountain I saw from the Vatna Jökull, situated in its S.W. limb, which I think may repay inspection; and the lignite in the N.W. of Iceland.

"The destruction wrought by the eruptions of last winter is considerable. Several farms have been ruined by pumice and ash. Poor, dirty, interesting Iceland! both fire and water, the latter in all its forms, appear to conspire against it."

## ON AN IMPROVED OPTICAL ARRANGEMENT FOR AZIMUTHAL CONDENSING APPARATUS FOR LIGHTHOUSES

ORDINARY optical apparatus adapted for a lighthouse which has to illuminate the whole horizon, as at rock or insular stations, is unsuitable for stations situate on the coast line, or in narrow sounds, where the light has in some azimuths to be seen at great distances, in others at smaller, and where towards the land no light is wanted at all. The problem in such cases is to allocate the rays in the different azimuths in proportion to the distances and breadths of sea in which the light requires to be seen in those directions by the sailor. Before 1855 no attempt

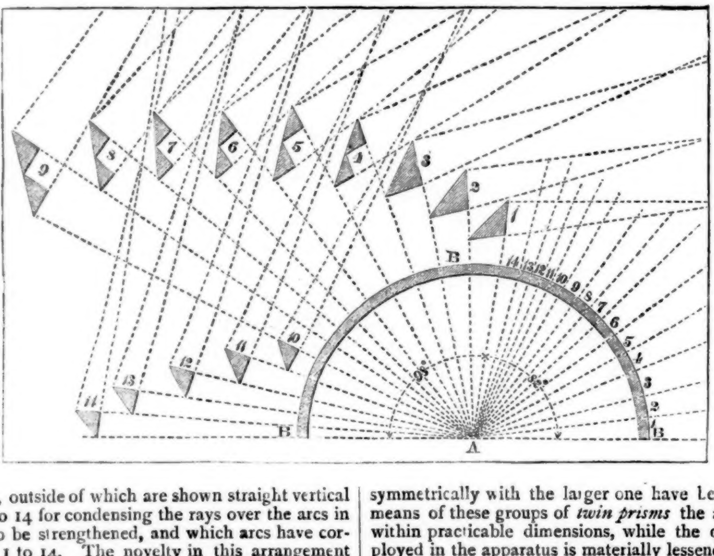
was made to deal with this question, excepting the simple expedient of placing a spherical mirror on the landward side, where no light was wanted, and thus the rays intercepted by the mirror were reflected back again through the flame, so as to be ultimately acted on by the apparatus at the seaward side. But this device did not in any way fulfil the condition of allocating the rays proportionally to the varying distances at which the light had to be seen in the different azimuths, nor to the amplitude of the arcs. What was required was *a system by which the whole light from the lamp should be spread horizontally and with strict equality over any given arc in azimuth; and at a light of unequal range, which must be seen at different distances in different azimuths, the rays should be allocated to each of such arcs in the compound ratio of the number of degrees and the distances from which the light has to be seen in such arcs.*

It is unnecessary to give a description of the various methods of solving this problem for fixed and revolving lights, which I have elsewhere published under the name of "Azimuthal Condensing Lights."[1] All that is here required is to indicate generally the mode of dealing with fixed condensing lights, which was first employed for some narrow navigable channels on the west coast of Scotland in 1857, and which is now adopted in many different countries.

We shall take a case of the simplest kind in order to illustrate the principle:—

Let a lamp be surrounded by the fixed light apparatus of Fresnel, which allows the rays to pass through it unaltered in direction in azimuth, so as thus to show a light of equal intensity all round the horizon, but which operates on the rays in altitude by bending upwards, to the horizontal, those rays which would fall on the lightroom floor and be lost, and also by bending downwards to the horizontal those rays which would naturally pass up to the clouds. This instrument then strengthens the light passing to the sailor's eye, by bending upwards and downwards those rays which would otherwise be entirely lost. Suppose, however, that the light does not require to be seen at all in an arc in the direction of the land, and that there are two other sectors in azimuth in which the light has to be seen at greater distances than any others. If we place outside of Fresnel's apparatus in the azimuths towards the land (which may therefore be made dark) straight prisms which have each the property of spreading the light that falls on them over the sectors that require most strength, and if we proportion the number of these straight prisms to the required distances and to the number of degrees which have to be illuminated, we shall then fulfil this simplest case of the problem, viz., the due strengthening of the light in the directions of the longest ranges, and its uniform distribution in azimuth over those sectors.

The diagram represents in horizontal middle section the design for a new light which is about to be erected and which requires to illuminate different arcs with light of different intensity. A is the lamp encircled in front by B, which represents part of Fresnel's



fixed light apparatus, outside of which are shown straight vertical prisms numbered 1 to 14 for condensing the rays over the arcs in azimuth that have to be strengthened, and which arcs have corresponding numbers 1 to 14. The novelty in this arrangement is the mode adopted for reducing the space which would otherwise be occupied by the condensing prisms but for which there is no room in a lantern of ordinary size.

My friend Prof. Swan, of St. Andrews, among other ingenious devices in a paper read to the Royal Scottish Society of Arts, proposed, in order to reduce the space occupied by the apparatus, to place prisms *behind* others and to project the rays from the prisms behind, forwards through spaces left between the prisms in front. In the present design I have availed myself of this proposal. The prisms 10 to 14 throw their light between the prisms 3 to 8. Owing, however, to the natural divergence due to the size of the flame, much useful light would be lost by impinging against the edges of the outer prisms unless those prisms were separated farther from each other in order to afford wider spaces for the cones of light to pass through. But this again would increase the space occupied by the apparatus. The difficulty may be overcome by cutting out the apex of the outer prisms as shown in prisms 4 to 9. This would, as in Buffon's annular lens, also materially reduce the absorption of the light which passes through them. For facility of construction, however, instead of one prism cut in this manner, two small separate prisms arranged symmetrically with the larger one have been substituted.[1] By means of these groups of *twin prisms* the apparatus is reduced within practicable dimensions, while the quantity of glass employed in the apparatus is materially lessened, and the loss from absorption is reduced by about one-tenth.

It is only necessary to add that while the cost of the first apparatus of the kind will be increased by the greater number of moulds required for casting the prisms, it will on the other hand be reduced by the smaller quantity of glass required. The amount of glass surface which has to be ground and polished is of course the same for each pair of twin prisms as for one single large prism.

The new apparatus will, in addition to what has been described, require at the back of the flame the Dioptric spherical mirror which I proposed in 1849[2] with the improvements suggested by Mr. J. T. Chance in 1862, and above the flame, prisms of the new forms suggested by Mr. Brebner and myself, and also independently by Prof. Swan, and which were first introduced at Lochindaal in Argyllshire, in 1869.[3] The apparatus will therefore embrace in all six different optical agents, and will compress into one sector of 82° light which would naturally diverge uselessly over 278°. This condensing apparatus is, however, not nearly so powerful as others now in use. In the two

[1] Edin. New Phil. Journal, 1855, p. 273. "Lighthouse Illumination," Edinburgh, 1871; second edition, p. 79.

[1] If the prism be of large size, more than two prisms may of course be substituted.
[2] Trans. Roy. Scott. Soc. of Arts, 1850.
[3] "Lighthouse Illumination," p. 75.

which I designed for Buddonness-on-the-Tay, one of which was exhibited at the Paris International Exhibition, the whole sphere of light was compressed into one sector of 45°, and in another design lately made for the Colonies the light is condensed into 30°.

THOMAS STEVENSON

## THE BRITISH ASSOCIATION

BRISTOL, *Tuesday Evening*

BRISTOL bids fair fully to accomplish its intention of giving the Association one of the best receptions it has ever received. When the visitor has laboured through the inconveniences of the railway station, and got fairly at home in this region of hills and valleys, and cliffs and quays, and churches and chimney stacks, he will find himself as happily situated as anyone but a confirmed grumbler could wish.

The local committee have evidently spared no expense to increase the comfort of visitors. The engagement of the entire Victoria Rooms for reception rooms has given ample space for almost every requirement. The great hall itself contains many of the necessary offices, including those for the local officials, sale of tickets of all kinds, distribution of printed circulars, and a telegraph and post-office; in addition, Messrs. Bingham's book-stall supplies all kinds of journals and scientific publications. A first-rate refreshment room occupies one of the smaller halls, and a reasonable tariff of prices is published. Almost every want seems to have been anticipated, and the honorary local secretaries, Messrs. W. Lant Carpenter and J. F. Clarke, with many other zealous workers, have been labouring untiringly to have everything in order. So successful were they, that the reception rooms were opened exactly at the moment previously announced—one o'clock on Monday; and the first rush to secure tickets was most satisfactorily worked off. It will be surprising if the amount expended do not exceed the local subscription of 2,400*l*. At any rate, so far as experience goes at present, that full success is likely to be realised which is worth very much more than can be measured by money. The Mayor (Mr. Thomas) to-day took up his residence at the Mansion House, where he will receive the President-elect, Lady Hawkshaw, and other distinguished visitors. Most of the notable visitors come as invited guests.

The columns of NATURE would certainly fail me if I attempted to enumerate the objects of interest here which are thrown open freely to members of the Association. Churches, old buildings of all kinds, libraries, ships, quays, warehouses, parks, and mansions are alike at the disposal of the visitors.

Notable amongst hospitalities will be the banquet of the Merchant Venturers' Society, at which about a hundred of the leading members of the Association will be entertained on Tuesday evening next. The hall of the Merchant Venturers has lately been decorated with a magnificence worthy of their distinguished history. The sovereigns who granted them charters, the Bristol worthies, Edward Colston, Alderman Whitson, Sebastian Cabot, William Canynge, and Thomas Daniel are all commemorated by portraits or arms; while the staircase and vestibule bear significant emblems of seafaring life. Saturday next is the jubilee of the Bath Royal Literary and Scientific Institution. This will be celebrated by a public meeting and banquet, presided over by the Earl of Cork, lord-lieutenant of the county. Sir John Hawkshaw and many other distinguished guests are expected.

As a matter of course nearly all the eminent British men of science are expected to be present, and many of them have already arrived. Among foreign visitors who have arrived or are expected, there are Prof. Paul Gervais, of Paris; Chevalier Negri, President of the Geographical Society of Turin; Chevalier Bergeron, C.E., Paris; Prof. Geinitz, Dresden; Prof. Hébert, Paris; Dr. Leitner; Prof. Youmans, United States; Mr. H. A. Rowland, Baltimore; Prof. Janssen, Paris; M. Léon Vanderkinden, Brussels University; Dr. A. Oppenheim, Berlin; Colonel Carrington, Wabash College, U.S.

Of course the general meetings, inaugural address, lectures, and soirées will be given in the Colston's Hall, which can seat 3,000 persons. The sections are accommodated in a number of buildings extending along one line of thoroughfare, from the Wesleyan schoolroom in Victoria Place to the Royal Hotel at College Green. Sections A and G sit in the Fine Arts Academy; B in the Lecture Theatre, Freemasons' Hall; C in the New Museum Lecture Room; D in three departments at Hamilton's Rooms, Park Street, the Grammar School, and the Royal Hotel; E in the Blind Asylum Music Room; F in the schoolroom of Victoria Chapel. On the back of every Association Ticket a plain map of about one square mile of Clifton is printed, showing in red colours all the buildings used for meetings. This is a most valuable help for visitors.

A first-rate loan museum is exhibited in the new portion of the Museum buildings, and is well worthy of attention. Among the most interesting things to be seen are specimens from many local collieries of every vein of coal they work, local building-stones and clays; and capital illustrations of local zoology and botany. The Museum proper is noticeable for its splendid collection of Triassic reptiles, Labyrinthodonts, and Palæozoic fishes, especially *Thecodontosaurus* and *Ceratodus*. A splendid skeleton of *Ichthyosaurus platyodon* has just been mounted. It was detected by Mr. Tawney on the beach near Lyme Regis, close to low-water mark. It was brought up in large fragments of over a hundred-weight, in all over a ton, and developed under Mr. Tawney's superintendence. The skeleton is swung instead of being supported from beneath, according to an idea of Dr. H. Fripp, and it can be examined very closely, and on both sides, being placed on a stand of the ordinary height of table cases. It was an enormous individual. The present remains, although lacking the snout and much of the tail, extend to a length of about twenty-five feet.

The excursions for Thursday week are numerous and calculated to please all tastes; they are to (1) Bath, (2) Bowood and Avebury, (3) Cheddar, (4) Chepstow and Tintern, (5) Portishead, Cadbury Camp, and Clevedon, (6) Salisbury and Stonehenge, (7) Sources of Bristol Waterworks Supply, (8) Tortworth and Damery Bridge, (9) Wells and Cheddar, (10) Weston-super-Mare.

The arrangements for transit and entertainment are most complete. The soirées give promise of great success. The first is to be under the auspices of the Bristol and Bath Natural History Societies, and many specimens of living microscopic animals will be exhibited. At the second, the post office officials intend to make a very elaborate display of telegraphic instruments and processes.

It is worthy of remark that it was at the meeting of the Association at Bristol in 1836 that Section G (Mechanical) was instituted; and at that meeting Dr. Lardner expressed his opinion that the proposed scheme of crossing the Atlantic by steam was an impossibility. From Bristol, however, the first steam-ship traversed the Atlantic to New York.

It was in the Bristol district that macadamised roads were first introduced; some of the earliest docks (1803) were made there under the direction of Mr. W. Jessop; and on the Somersetshire Canal was tried Mr. Weldon's extraordinary hydrostatic lock.

To geologists there is the interesting fact that within twelve miles on the Somersetshire Coal Canal, the "father of English geology" made his discovery of the sequence of strata; and geographers will recollect that Sebastian Cabot sailed from Bristol.

### INAUGURAL ADDRESS OF SIR JOHN HAWKSHAW, F.R.S., PRESIDENT.

To those on whom the British Association confers the honour of presiding over its meetings, the choice of a subject presents some difficulty.

The Presidents of Sections, at each annual meeting, give an account of what is new in their respective departments; and essays on science in general, though desirable and interesting in the earlier years of the Association, would be less appropriate to-day.

Past Presidents have already discoursed on many subjects, on things organic and inorganic, on the mind and on things perhaps beyond the reach of mind, and I have arrived at the conclusion that humbler themes will not be out of place on this occasion.

I propose in this Address to say something of a profession to which my lifetime has been devoted—a theme which cannot perhaps be expected to stand as high in your estimation as in my own, and I may have some difficulty in making it interesting; but I have chosen it because it is a subject I ought to understand better than any other. I propose to say something on its origin, its work, and kindred topics.

Rapid as has been the growth of knowledge and skill as applied to the art of the engineer during the last century, we must, if we would trace its origin, seek far back among the earliest evidences of civilisation.

In early times, when settled communities were few and isolated, the opportunities for the interchange of knowledge were scanty or wanting altogether. Often the slowly accumulated results of the experience of the wisest heads and the most skilful hands of a community were lost on its downfall. Inventions of one period were lost and found again. Many a patient investigator has puzzled his brain in trying to solve a problem which had yielded to a more fortunate labourer in the same field some centuries before.

The ancient Egyptians had a knowledge of Metallurgy, much of which was lost during the years of decline which followed the golden age of their civilisation. The art of casting bronze over iron was known to the Assyrians, though it has only lately been introduced into modern metallurgy; and patents were granted in 1609 for processes connected with the manufacture of glass, which had been practised centuries before.[1] An inventor in the reign of Tiberius devised a method of producing flexible glass, but the manufactory of the artist was totally destroyed, we are told, in order to prevent the manufacture of copper, silver, and gold from becoming depreciated.[2]

Again and again engineers as well as others have made mistakes from not knowing what those had done who have gone before them, and have had the same difficulties to contend with. In the long discussion which took place as to the practicability of making the Suez Canal, an early objection was brought against it that there was a difference of 32½ feet between the level of the Red Sea and that of the Mediterranean. Laplace at once declared that such could not be the case, for the mean level of the sea was the same on all parts of the globe. Centuries before the time of Laplace the same objection had been raised against a project for joining the waters of these two seas. According to the old Greek and Roman historians, it was a fear of flooding Egypt with the waters of the Red Sea that made Darius, and in later times again Ptolemy, hesitate to open the canal between Suez and the Nile.[3] Yet this canal was made, and was in use some centuries before the time of Darius.

Strabo[4] tells us that the same objection, that the adjoining seas were of different levels, was made by his engineers to Demetrius,[5] who wished to cut a canal through the Isthmus of Corinth some two thousand years ago. But Strabo[6] dismisses at once this idea of a difference of level, agreeing with Archimedes that the force of gravity spreads the sea equally over the earth.

When knowledge in its higher branches was confined to a few, those who possessed it were often called upon to perform many and various services for the communities to which they belonged; and we find mathematicians and astronomers, painters and sculptors, and priests called upon to perform the duties which now pertain to the profession of the architect and the engineer. And as soon as civilisation had advanced so far as to admit of the accumulation of wealth and power, then kings and rulers sought to add to their glory while living by the erection of magnificent dwelling-places, and to provide for their aggrandizement after death by the construction of costly tombs and temples. Accordingly we soon find men of ability and learning devoting a great part of their time to building and architecture, and the post of architect became one of honour and profit. In one of the most ancient quarries of Egypt a royal high architect of the dynasty of the Psammetici has left his pedigree sculptured on the rock, extending back for twenty-three generations, all of whom held the same post in succession in connection with considerable sacerdotal offices.[1]

As there were in these remote times officers whose duty it was to design and construct, so also there were those whose duty it was to maintain and repair the royal palaces and temples. In Assyria, 700 years before our era, as we know from a tablet found in the palace of Sennacherib by Mr. Smith, there was an officer whose title was the Master of Works. The tablet I allude to is inscribed with a petition to the king from an officer in charge of a palace, requesting that the master of works may be sent to attend to some repairs which were much needed at the time.[2]

Under the Roman Empire there was almost as great a division of labour in connection with building and design as now exists. The great works of that period were executed and maintained by an army of officers and workmen, who had special duties assigned to each of them.

Passing by those early attempts at design and construction which supplied the mere wants of the individual and the household, it is to the East that we must turn if we would find the earliest works which display a knowledge of engineering. Whether the knowledge of engineering, if we may so call it, possessed by the people of Chaldæa and Babylonia was of native growth or was borrowed from Egypt is, perhaps, a question which cannot yet be answered. Both people were agricultural, dwelling on fertile plains, intersected by great rivers, with a soil requiring water only to enable it to bring forth inexhaustible crops. Similar circumstances would create similar wants, and stimulate to action similar faculties to satisfy them. Apart from the question of priority of knowledge, we know that at a very early period, some four or five thousand years ago at least, there were men in Mesopotamia and Egypt who possessed considerable mechanical knowledge, and no little skill in hydraulic engineering. Of the men themselves we know little; happily, works often remain when the names of those who conceived and executed them have long been forgotten.

It has been said that architecture had its origin not only in nature, but in religion; and if we regard the earliest works which required mechanical knowledge and skill, the same may be said of engineering. The largest stones were chosen for sacred buildings, that they might be more enduring as well as more imposing, thereby calling for improvement and invention of mechanical contrivances, to assist in transporting and elevating them to the position they were to occupy; for the same reason the hardest and most costly materials were chosen, calling for further improvement in the metal forming the tools required to work them. The working of metals was further perfected in making images of the gods, and in adorning with the more precious and ornamental sorts the interior and even external parts of their shrines.

The earliest buildings of stone to which we can assign a date with any approach to accuracy, are the pyramids of Gizeh. To their builders they were sacred buildings, even more sacred than their temples or temple palaces. They were built to preserve the royal remains, until, after a lapse of 3,000 years, which we have reason to believe was the period assigned, the spirit which had once animated the body should re-enter it.[3] Although built 5,000 years ago, the masonry of the Pyramids could not be surpassed in these days; all those who have seen and examined them, as I myself have done, agree in this; moreover, the design is perfect for the purpose for which they were intended, above all to endure. The building of pyramids in Egypt continued for some ten centuries, and from 60 to 70 still remain, but none are so admirably constructed as those of Gizeh. Still, many contain enormous blocks of granite from 30 to 40 feet long, weighing more than 300 tons, and display the greatest ingenuity in the way in which the sepulchral chambers are constructed and concealed.[4]

1 Layard's "Nineveh and Babylon," p. 191; Beckman's "History of Inventions," vol. ii. p. 85.
2 Pliny, Nat. Hist., bk. xxxvi. c. 66.
3 Ibid., bk. vi. c. 33.
4 Strabo, c. iii. § 11.
5 Demetrius I., King of Macedonia, died 283 B.C.
6 Strabo, c. iii. § 12.

1 "Discoveries in Egypt, Ethiopia, &c.," by Dr. Lepsius, 2nd edit. p. 318
2 Smith's (G.) "Assyrian Discoveries," 2nd edit. p. 414.
3 Fergusson's "History of Architecture," vol. i. p. 83; Wilkinson "Ancient Egyptians," 2nd series, vol. ii. p. 444.
4 Vyse's "Pyramid's of Gizeh," vol. iii. pp. 16, 41, 45, 57.

The genius for dealing with large masses in building did not pass away with the pyramid builders in Egypt, but their descendants continued to gain in mechanical knowledge, judging from the enormous blocks which they handled with precision. When the command of human labour was unlimited, the mere transport of such blocks as the statue of Rameses the Great, for instance, which weighed over 800 tons, need not so greatly excite our wonder; and we know how such blocks were moved from place to place, for it is shown on the wall paintings of tombs of the period which still remain.

But as the weight of the mass to be moved is increased, it becomes no longer a question of only providing force in the shape of human bone and muscle. In moving in the last century the block which now forms the base for the statue of Peter the Great, at St. Petersburg, and which weighs 1,200 tons, force could be applied as much as was wanted, but great difficulty was experienced in supporting it, and the iron balls on which it was proposed to roll the block along were crushed, and a harder metal had to be substituted.[1] To facilitate the transport of material, the Egyptians made solid causeways of granite from the Nile to the Pyramids; and in the opinion of Herodotus, who saw them, the causeways were more wonderful works than the Pyramids themselves.[2]

The Egyptians have left no record of how they accomplished a far more difficult operation than the mere transport of weight—that is, how they erected obelisks weighing more than 400 tons. Some of these obelisks must have been lifted vertically to place them in position, as they were by Fontana in Rome in later times, when the knowledge of mechanics, we know, was far advanced.[3]

The practice of using large blocks of stone either as monoliths or as forming parts of structures has existed from the earliest times in all parts of the world.

The Peruvians used blocks weighing from 15 to 20 tons, and fitted them with the greatest nicety in their cleverly designed fortifications.[4]

In India large blocks were used in bridges when the repugnance of Indian builders to the use of the arch rendered them necessary, or in temples, where, as in the Temple of the Sun at Orissa, stones weighing from 20 to 30 tons form part of the pyramidal roof at a height of from 70 to 80 feet from the ground.[5] Even as late as the last century, Indians, without the aid of machinery, were using blocks of granite above 40 feet long for the doorposts of the gateway of Seringham, and roofing blocks of the same stone for a span of 21 feet.[6]

At Persepolis, in the striking remains of the palaces of Xerxes and Darius, more than one traveller has noted the great size of the stones, some of which are stated to be 55 feet long and 6 to 10 feet broad.

So in the Greek temples of Sicily, many of the blocks in the upper parts of the temples are from 10 to 20 tons weight.

The Romans, though they did not commonly use such large stones in their own constructions, carried off the largest obelisks from Egypt and erected them at Rome, where more are now to be found than remain in Egypt. In the temples of Baalbek, erected under Roman rule, perhaps the largest stones are to be found which have been used for building since the time of the Pharaohs. The terrace wall of one of the temples is composed of three courses of stones, none of which are less than 30 feet long; and one stone still lies in the quarry squared and ready for transport, which is 70 feet long and 14 feet square, and weighs upwards of 1,135 tons, or nearly as much as one of the tubes of the Britannia Bridge.

I have not mentioned dolmens and menhirs, rude unhewn stones often weighing from 30 or 40 tons, which are found from Ireland to India, and from Scandinavia to the Atlas, in Africa. To transport and erect such rude masses required little mechanical knowledge or skill, and the operation has excited more wonder than it deserves. Moreover, Fergusson has gone far to show that the date assigned to many of them hitherto has been far too remote; most, and possibly all, of those in northern and western Europe having been erected since the time of the Roman occupation. And to this day the same author shows that menhirs, single stones often weighing over 20 tons, are erected by hill tribes of India in close proximity to stone buildings of elaborate design and finished execution, erected by another race of men.[1]

For whatever purpose these vast stones were selected—whether to enhance the value or to prolong the endurance of the buildings of which they formed a part—the tax on the ingenuity of those who moved and placed them must have tended to advance the knowledge of mechanical appliances.

The ancient Assyrians and Egyptians had possibly more knowledge of mechanical appliances than they are generally credited with. In the wall paintings and sculptures which show their mode of transporting large blocks of stone, the lever is the only mechanical power represented, and which they appear to have used in such operations; nor ought we to expect to find any other used, for, where the supply of human labour was unlimited, the most expeditious mode of dragging a heavy weight along would be by human power; to have applied pulleys and capstans, such as would now be employed in similar undertakings, would have been mere waste of time. In some countries, even now, where manual labour is more plentiful than mechanical appliances, large numbers of men are employed to transport heavy weights, and do the work in less time than it could be done with all our modern mechanical appliances. In other operations, such as raising obelisks, or the large stones used in their temple palaces, where human labour could not be applied to such advantage, it is quite possible that the Egyptians used mechanical aids. On one of the carved slabs which formed part of the wall panelling of the palace of Sardanapalus, which was built about 930 years before our era, a single pulley is clearly shown, by which a man is in the act of raising a bucket—probably drawing water from a well.[2]

It has sometimes been questioned whether the Egyptians had a knowledge of steel. It seems unreasonable to deny them this knowledge. Iron was known at the earliest times of which we have any record. It is often mentioned in the Bible, and in Homer; it is shown in the early paintings on the walls of the tombs at Thebes, where butchers are represented as sharpening their knives on pieces of metal coloured blue, which were most probably pieces of steel.[3] Iron has been found in quantity in the ruined palaces of Assyria; and in the inscriptions of that country fetters are spoken of as having been made of iron, which is also so mentioned in connection with other metals as to lead to the supposition that it was regarded as a base and common metal. Moreover, in the Great Pyramid a piece of iron was found in a place where it must have lain for 5,000 years.[4] The tendency of iron to oxidize must render its preservation for any long period rare and exceptional. The quality of iron which is now made by the native races of Africa and India is that which is known as wrought iron; in ancient times, Dr. Percy says the iron which was made was always wrought iron. It is very nearly pure iron, and a very small addition of carbon would convert it into steel. Dr. Percy says the extraction of good malleable iron directly from the ore "requires a degree of skill very far inferior to that which is implied in the manufacture of bronze."[5] And there is no great secret in making steel; the natives of India now make excellent steel in the most primitive way, which they have practised from time immemorial. When steel is to be made, the proportion of charcoal used with a given quantity of ore is somewhat larger, and the blast is applied more slowly than when wrought iron is the metal required.[6] Thus, a vigorous native working the bellows of skin would make wrought iron where a lazy one would have made steel. The only apparatus required for the manufacture of the finest steel from iron ore is some clay for making a small furnace four feet high, and from one to two broad, some charcoal for fuel, and a skin with a bamboo tuyere for creating the blast.

The supply of iron in India as early as the fourth and fifth centuries seems to have been unlimited. The iron pillar of Delhi is a remarkable work for such an early period. It is a single piece of wrought iron 50 feet in length, and it weighs not less than 17 tons.[7] How the Indians forged this large mass of iron and other heavy pieces which their distrust of the arch led them to use in the construction of roofs, we do not know. In the

[1] Rondelet's "Traité de l'Art de Bâtir,' vol. i. p. 73.
[2] Herodotus, bk. ii. c. 124.
[3] For obelisk erected at Arles, 1676, see Rondelet's "L'Art de Bâtir," vol. i. p. 48. Its weight was nearly 200 tons, and it was suspended vertically by light ships' masts.
[4] Fergusson's "History of Architecture," vol. ii. p. 779; Squier, "Peru," p. 24.
[5] The Temple of the Sun was built 1237-1282 A.D.—Hunter's "Orissa," vol. i. pp. 288, 297.
[6] Fergusson's "Rude Stone Monuments," p. 96.

[1] Fergusson's "Rude Stone Monuments," pp 461-465.
[2] Layard's "Nineveh and its Remains," vol. ii. p. 31.
[3] Wilkinson's "Ancient Egyptians," vol. iii. p. 247.
[4] Vyse's "Pyramids of Gizeh," vol. i. p. 275.
[5] Percy's "Iron and Steel," p. 873.
[6] Ibid. p. 259.
[7] Fergusson's "History of Architecture," vol. ii. p. 460; and "Rude Stone Monuments," pp. 481–3. Cunningham's "Archæological Survey of India," vol. i. p. 169.

temples of Orissa iron was used in large masses as beams or girders in roof-work in the thirteenth century.[1]

The influence of the discovery of iron on the progress of art and science cannot be over-estimated. India well repaid any advantage which she may have derived from the early civilised communities of the West if she were the first to supply them with iron and steel.

An interesting social problem is afforded by a comparison of the relative conditions of India and this country at the present time. India, from thirty to forty centuries ago, was skilled in the manufacture of iron and cotton goods, which manufactures, in less than a century, have done so much for this country. It is true that in India coal is not so abundant or so universally distributed as in this country. Yet, if we look still further to the East, China had probably knowledge of the use of metals as soon as India, and moreover had a boundless store of iron and coal. Baron Richthofen, who has visited and described some of the coal-fields of China, believes that one province alone, that of Southern Shanshi, could supply the world at its present rate of consumption for several thousand years. The coal is near the surface, and iron abounds with it. Marco Polo tells us that coal was universally used as fuel in the parts of China which he visited towards the end of the fourteenth century, and from other sources we have reason to believe it was used there as fuel 2,000 years ago. But what progress has China made in the last ten centuries? A great future is undoubtedly in store for that country; but can the race who now dwell there develop its resources, or must they await the aid of an Aryan race? Or is anything more necessary than a change of institutions, which might come unexpectedly, as in Japan?

The art of extracting metals from the ore was practised at a very early date in this country. The existence long ago of tin mines in Cornwall, which are so often spoken of by classical writers, is well known to all. That iron was also extracted from the ore by the ancient Britons is most probable, as it was largely used for many purposes by them before the Roman conquest. The Romans worked iron extensively in the Weald of Kent, as we assume from the large heaps of slag containing Roman coins which still remain there. The Romans always availed themselves of the mineral wealth of the countries which they conquered, and their mining operations were often carried out on the largest scale, as in Spain, for instance, where as many as forty thousand miners were regularly employed in the mines at New Carthage.[2]

Coal, which was used for ordinary purposes in England as early as the ninth century, does not appear to have been largely used for iron smelting until the eighteenth century, though a patent was granted for smelting iron with coal in the year 1611.[3] The use of charcoal for that purpose was not given up until the beginning of this century, since which period an enormous increase in the mining and metallurgical industries has taken place; the quantity of coal raised in the United Kingdom in 1873 having amounted to 127 million tons, and the quantity of pig iron to upwards of 6½ million tons.

The early building energy of the world was chiefly spent on the erection of tombs, temples, and palaces.

While, in Egypt, as we have seen, the art of building in stone had 5,000 years ago reached the greatest perfection, so in Mesopotamia the art of building with brick, the only available material in that country, was in an equally advanced state some ten centuries later. That buildings of such a material have lasted to this day shows how well the work was done; their ruinous condition even now is owing to their having served as quarries for the last three or four thousand years, so that the name of Nebuchadnezzar, apparently one of the greatest builders of ancient times, is as common on the bricks of many modern towns in Persia as it was in old times in Babylon. The labour required to construct the brick temples and palaces of Chaldæa and Assyria must have been enormous. The mound of Koyunjik alone contained 14½ million tons, and represents the labour of 10,000 men for twelve years. The palace of Sennacherib, which stood on this mound, was probably the largest ever built by any one monarch, containing as it did more than two miles of walls, panelled with sculptured alabaster slabs, and twenty-seven portals, formed by colossal bulls and sphinxes.[4]

The pyramidal temples of Chaldæa are not less remarkable for the labour bestowed on them, and far surpass the buildings of Assyria in the excellence of their brickwork.

The practice of building great pyramidal temples seems to have passed eastwards to India and Burmah, where it appears in buildings of a later date, in Buddhist topes and pagodas; marvels of skill in masonry, and far surpassing the old brick mounds of Chaldæa in richness of design and in workmanship. Even so late as this century a king of Burmah began to build a brick temple of the old type, the largest building, according to Fergusson, which has been attempted since the Pyramids.[1]

The mere magnitude of many of these works is not so wonderful when we take into account the abundance of labour which those rulers could command. Countries were depopulated, and their inhabitants carried off and made to labour for the conquerors. The inscriptions of Assyria describe minutely the spoils of war and the number of captives; and in Egypt we have frequent mention made of works being executed by the labour of captive peoples. Herodotus tells us that as many as 360,000 men were employed in building one palace for Sennacherib.[2] At the same time it must not be forgotten that the very character of the multitude would demand from some one the skill and brain to organise and direct, to design and plan the work.

It would be surprising if men who were capable of undertaking and successfully completing unproductive works of such magnitude did not also employ their powers on works of a more useful class. Traces still remain of such works; enough to show, when compared with the scanty records of the times which have come down to us, that the prosperity of such countries as Egypt and Mesopotamia was not wholly dependent on war and conquest, but that the reverse was more likely the case, and that the natural capabilities of those countries were greatly enlarged by the construction of useful works of such magnitude as to equal, if not in some cases surpass, those of modern times.

Egypt was probably far better irrigated in the days of the Pharaohs than it is now. To those unacquainted with the difficulties which must be met with and overcome before a successful system of irrigation can be carried out, even in countries in which the physical conditions are favourable, it may appear that nothing more is required than an adequate supply of unskilled labour. Far more than this was required: the Egyptians had some knowledge of surveying, for Eustathius says they recorded their marches on maps;[3] but such knowledge was probably in those days very limited, and it required no ordinary grasp of mind to see the utility of such extensive works as were carried out in Egypt and Mesopotamia, and, having seen the utility, to successfully design and execute them. To cite one in Egypt—Lake Mœris, of which the remains have been explored by M. Linant, was a reservoir made by one of the Pharaohs, and supplied by the flood waters of the Nile. It was 150 square miles in extent, and was retained by a bank or dam 60 yards wide and 10 high, which can be traced for a distance of thirteen miles. This reservoir was capable of irrigating 1,200 square miles of country.[4] No work of this class has been undertaken on so vast a scale since, even in these days of great works.

The prosperity of Egypt was in so great a measure dependent on its great river, that we should expect that the Egyptians, a people so advanced in art and science, would at an early period have made themselves acquainted with its *régime*. We know that they carefully registered the height of the annual rise of its waters; such registers still remain inscribed on the rocks on the banks of the Nile, with the name of the king in whose reign they were made.[5] The people of Mesopotamia were equally observant of the *régime* of their great rivers, and took advantage in designing their canals of the different periods in the rising of the waters of the Tigris and Euphrates. A special officer was appointed in Babylon, whose duty it was to measure the rise of the river; and he is mentioned in an inscription found in the ruins of that city, as recording the height of the water in the temple of Bel.[6] The Assyrians, who had a far more difficult country to deal with, owing to its rocky and uneven surface, showed even greater skill than the Babylonians in forming their canals, tunnelling through rock, and building dams of masonry across the Euphrates. While the greater number of these canals in Egypt and Mesopotamia were made for the purpose of irrigation, others seem to have been made to serve at the same time

[1] Hunter's "Orissa," vol. i. p. 298.
[2] Strabo. bk. iii. c. ii. § 10.
[3] Percy's "Iron and Steel," p. 882.
[4] Layard's "Nineveh and Babylon," p. 589.

[1] Fergusson's "History of Architecture," vol. ii. p. 523.
[2] Rawlinson's "Herodotus," vol. i. p. 389, 2nd edit.
[3] Ibid. vol. ii. p. 278, 2nd edit.
[4] M. Linant's "Mémoire sur le lac Mœris."
[5] Lepsius' "Discoveries in Egypt, &c.," p. 268.
[6] Smith's "Assyrian Discoveries," pp. 395–7, 2nd edit.

for navigation. Such was the canal which effected a junction between the Mediterranean and the Red Sea, which was a remarkable work, having regard to the requirements of the age in which it was made. Its length was about eighty miles; its width admitted of two triremes passing one another.[1] At least one of the navigable canals of Babylonia, attributed to Nebuchadnezzar, can compare in extent with any work of later times. I believe Sir H. Rawlinson has traced the canal to which I allude throughout the greater part of its course, from Hit on the Euphrates to the Persian Gulf, a distance of between four and five hundred miles.[2] It is a proof of the estimation in which such works were held in Babylonia and Assyria, that, among the titles of the god Vul were those of "Lord of Canals," and "The Establisher of Irrigation Works."[3]

The springs of knowledge which had flowed so long in Babylonia and Assyria were dried up at an early period. With the fall of Babylon and destruction of Nineveh the settled population of the fertile plains around them disappeared, and that which was desert before man led the waters over it became desert again, affording a wide field for, and one well worthy of, the labours of engineers to come.

Such was not the case with Egypt. Long after the period of its greatest prosperity was reached, it remained the fountain head from whence knowledge flowed to Greece and Rome. The philosophers of Greece and those who, like Archimedes, were possessed of the best mechanical knowledge of the time, repaired to Egypt to study and obtain the foundation of their knowledge from thence.

Much as Greece and Rome were indebted to Egypt, it will probably be found, as the inscribed tablets met with in the mounds of Assyria and Chaldæa are deciphered, that the later civilisations owe, if not more, at least as much, to those countries as to Egypt. This is the opinion of Mr. Smith, who, in his work describing his recent interesting discoveries in the East, says that the classical nations "borrowed far more from the valley of the Euphrates than that of the Nile."[4]

In the science of astronomy, which in these days is making such marvellous discoveries, Chaldæa was undoubtedly preeminent. Among the many relics of these ancient peoples which Mr. Smith has recently brought to this country is a portion of a metal astrolabe from the palace of Sennacherib, and a tablet on which is recorded the division of the heavens according to the four seasons, and the rule for regulating the intercalary month of the year. Not only did the Chaldæans map out the heavens and arrange the stars, but they traced the motion of the planets, and observed the appearance of comets; they fixed the signs of the zodiac, and they studied the sun and moon and the periods of eclipses.[5]

But to return to that branch of knowledge to which I wish more particularly to draw your attention, as it grew and spread from east to west, from Asia over Europe. Of all nations of Europe the Greeks were most intimately connected with the civilisation of the East. A maritime people by the nature of the land they lived in, colonisation followed as a matter of course on the tracks of their trading vessels; and thus, more than any other people, they helped to spread Eastern knowledge along the shores of the Mediterranean, and throughout the south of Europe.

The early constructive works of Greece, till about the seventh century B.C., form a strong contrast to those of its more prosperous days. Commonly called Pelasgian, they are more remarkable as engineering works than admirable as those which followed them were for architectural beauty. Walls of huge unshapely stones—admirably fitted together, however—tunnels, and bridges, characterise this period. In Greece, during the few and glorious centuries which followed, the one aim in all construction was to please the eye, to gratify the sense of beauty; and in no age was that aim more thoroughly and satisfactorily attained.

In these days, when sanitary questions attract each year more attention, we may call to mind that twenty-three centuries ago the city of Agrigentum possessed a system of sewers, which, on account of their large size, were thought worthy of mention by Diodorus.[6] This is not, however, the first record of towns being drained; the well-known Cloaca Maxima, which formed part of the drainage system of Rome, was built some two centuries earlier, and great vaulted drains passed beneath the palace mounds of unburnt brick at Nimroud and Babylon; and possibly we owe the preservation of many of the interesting remains found in the brick mounds of Chaldæa to the very elaborate system of pipe drainage discovered in them, and described by Loftus.[1]

Whilst Pelasgian art was being superseded in Greece, the city of Rome was founded in the eighth century before our era; and Etruscan art in Italy, like the Pelasgian art in Greece, was slowly merged in that of an Aryan race. The Etruscans, like the Pelasgians and the old Egyptians, were Turanians, and remarkable for their purely constructive or engineering works. Their city walls far surpass those of any other ancient race, and their drainage works and tunnels are most remarkable.

The only age which can compare with the present one in the rapid extension of utilitarian works over the face of the civilised world, is that during which the Romans, an Aryan race, as we are, were in power. As Fergusson has said, the mission of the Aryan races appears to be to pervade the world with useful and industrial arts. That the Romans adorned their bridges, their aqueducts, and their roads; that with a sound knowledge of construction they frequently made it subservient to decoration, was partly owing to the mixture of Etruscan or Turanian blood in their veins, and partly to their great wealth, which made them disregard cost in their construction, and to their love of display.

It would be impossible for me to do justice to even a small part of the engineering works which have survived fourteen centuries of strife, and remain to this day as monuments of the skill, the energy, and ability of the great Roman people. Fortunately, their works are more accessible than those of which I have spoken hitherto, and many of you are probably already familiar with them.

Conquerors of the greater part of the civilised world, the admirable organisation of the Romans enabled them to make good use of the unbounded resources which were at their disposal. Yet, while the capital was enriched, the development of the resources of the most distant provinces of the empire was never neglected.

War, with all its attendant evils, has often indirectly benefited mankind. In the long sieges which took place during the old wars of Greece and Rome, the inventive power of man was taxed to the utmost to provide machines for attack and defence. The ablest mathematicians and philosophers were pressed into the service, and helped to turn the scale in favour of their employers. The world has to regret the loss of more than one, who, like Archimedes, fell slain by the soldiery while applying the best scientific knowledge of the day to devising means of defence during the siege.[2] In these days, too, science owes much to the labours of engineers and able men, whose time is spent in making and improving guns, the materials composing them, and armour plates to resist them, or in studying the motion of ships of war in a seaway.

The necessity for roads and bridges for military purposes has led to their being made where the necessary stimulus from other causes was wanting; and so means of communication, and the interchange of commodities, so essential to the prosperity of any community, have thus been provided. Such was the case under the Roman Empire. So, too, in later times the ambition of Napoleon covered France and the countries subject to her with an admirable system of military roads. At the same time, we must do Napoleon the justice of saying that his genius and foresight gave a great impetus to the construction of all works favourable to commercial progress. So, again, in this country it was the rebellion of 1745, and the want felt of roads for military purposes, which first led to the construction of a system of roads in it unequalled since the time of the Roman occupation. And lastly, in India, in Germany, and in Russia, more than one example could be pointed out where industry will benefit by railways which have originated in military precautions rather than in commercial requirements.

But to return to Rome. Roads followed the tracks of her legions into the most distant provinces of the empire. Three hundred and seventy-two great roads are enumerated, together more than 48,000 miles in length, according to the itinerary of Antoninus.

The water supply of Rome during the first century of our era would suffice for a population of seven millions, supplied at the rate at which the present population of London is supplied. This water was conveyed to Rome by nine aqueducts; and in

[1] Herodotus, bk ii. c. clviii.
[2] Rawlinson's "Herodotus," vol. i. p. 420, 2nd edit.
[3] Ibid. p. 498.
[4] Smith's (G.) "Assyrian Discoveries," p. 451, 2nd edit.
[5] Ibid.
[6] Agrigentum was a celebrated Greek city, founded B.C. 582, population 200,000 (*Diodorus*, 406 B.C.), drained by Phœax, who lived B.C. 480.

[1] Rawlinson's "Five Ancient Monarchies," vol. i. pp. 89, 90, 2nd edit.
[2] Archimedes, B.C. 287-212; killed at the siege of Syracuse by the Roman soldiers.

later years the supply was increased by the construction of five more aqueducts. Three of the old aqueducts have sufficed to supply the wants of the city in modern times. These aqueducts of Rome are to be numbered among her grandest engineering works.[1] Time will not admit of my saying anything about her harbour works and bridges, her basilicas and baths, and numerous other works in Europe, in Asia, and in Africa. Not only were these works executed in a substantial and perfect manner, but they were maintained by an efficient staff of men divided into bodies, each having their special duties to perform. The highest officers of state superintended the construction of works, were proud to have their names associated with them, and constructed extensive works at their own expense.

Progress in Europe stopped with the fall of the Roman Empire. In the fourth and succeeding centuries the barbarian hordes of Western Asia, people who felt no want of roads and bridges, swept over Europe to plunder and destroy.

With the seventh century began the rise of the Mohammedan power, and a partial return to conditions apparently more favourable to the progress of industrial art, when widespread lands were again united under the sway of powerful rulers.[2] Science owes much to Arab scholars, who kept and handed on to us the knowledge acquired so slowly in ancient times, and much of which would have been lost but for them. Still, few useful works remain to mark the supremacy of the Mohammedan power at all comparable to those of the age which preceded its rise.

A great building age began in Europe in the tenth century, and lasted through the thirteenth. It was during this period that these great ecclesiastical buildings were erected, which are not more remarkable for artistic excellence than for boldness in design.

While the building of cathedrals progressed on all sides in Europe, works of a utilitarian character, which concern the engineer, did not receive such encouragement, excepting perhaps in Italy.

From the twelfth to the thirteenth centuries, with the revival of the arts and sciences in the Italian republics, many important works were undertaken for the improvement of the rivers and harbours of Italy. In 1481 canal locks were first used; and some of the earliest of which we have record were erected by Leonardo da Vinci, who would be remembered as a skilful engineer had he not left other greater and more attractive works to claim the homage of posterity.

The great use that has since been made of this simple means of transferring floating vessels from one water level to another, in connection not only with inland navigation, but in all the great ports and harbours of the world, renders it all the more deserving of remark.

In India, under the Moguls, irrigation works, for which they had a natural aptitude, were carried on during these centuries with vigour, and more than one emperor is noted for the numerous great works of this nature which he carried out. If the native records can be trusted, the number of hydraulic works undertaken by some rulers is surprising. Tradition relates that one king who reigned in Orissa in the twelfth century made one million tanks or reservoirs, besides building sixty temples, and erecting numerous other works.[3]

In India, the frequent overflow of the great rivers, and the periodical droughts, which rendered irrigation necessary, led to extensive protective works being undertaken at an early period; but as these works have been maintained by successive rulers, Mogul and Mohammedan, until recent times, and have not been left for our inspection, deserted and useless for 3,000 years or more, as is often the case in Egypt and Mesopotamia, there is more difficulty in ascertaining the date of such works in India.

Works of irrigation were among the earliest attempts at engineering undertaken by the least civilised inhabitants in all parts of the world. Even in Australia, where savages are found as low as any in the scale of civilisation, traces of irrigation works have been found; these works, however, must be taken to show that the natives were once somewhat more civilised than we now find them. In Feejee, our new possession, the natives occasionally irrigate their land,[4] and have executed a work of a

1 Total length 250 miles; 50 on arches, 200 underground.
2 "Under the last of the house of Ommiyah (750 A.D.) one command was obeyed almost along the whole diameter of the known world, from the banks of the Sihon to the utmost promontory of Portugal."—Hallam's "Middle Ages," vol. ii. p. 120, 2nd edit.
3 King Bhim Deo. A.D. 1174, 60 temples, 10 bridges, 40 wells stone cased, 152 landing stairs, and 1,000,000 tanks.—Hunter's "Orissa," vol. i. p. 100.
4 Erskine's "Western Pacific," p. 171.

higher class, a canal some two miles long and sixty feet wide, to shorten the distance passed over by their canoes.[1] The natives of New Caledonia irrigate their fields with great skill.[2] In Peru, the Incas excelled in irrigation as in other great and useful works, and constructed most admirable underground conduits of masonry for the purpose of increasing the fertility of the land.[3]

It is frequently easier to lead water where it is wanted than to check its irruption into places where its presence is an evil, often a disaster. For centuries the existence of a large part of Holland has been dependent on the skill of man. How soon he began in that country to contest with the sea the possession of the land we do not know, but early in the twelfth century dykes were constructed to keep back the ocean. As the prosperity of the country increased with the great extension of its commerce, and land became more valuable and necessary for an increasing population, very extensive works were undertaken. Land was reclaimed from the sea, canals were cut, and machines were designed for lifting water. To the practical knowledge acquired by the Dutch, whose method of carrying out hydraulic works is original and of native growth, much of the knowledge of the present day in embanking, and draining, and canal making is due. The North Holland Canal[4] was the largest navigable canal in existence until the Suez Canal was completed; and the Dutch have just now nearly finished making a sea canal from Amsterdam to the North Sea, which, though not equal to the Suez Canal in length, will be as great in width and depth, and involves perhaps larger and more important works of art. This country was for many years beholden to the Dutch for help in carrying out hydraulic works. In the seventeenth century much fen land in the eastern counties was drained by Dutch labour, directed by Dutch engineers, among whom Sir Cornelius Vermuyden, an old campaigner of the Thirty Years' War, and a colonel of horse under Cromwell, is the most noted.

While the Dutch were acquiring practical knowledge in dealing with water, and we in Britain among others were benefiting by their experience, the disastrous results which ensued from the inundations caused by the Italian rivers of the Alps gave a new importance to the science of hydraulics. Some of the greatest philosophers of the seventeenth century—among them Torricelli, a pupil of Galileo,[5]—were called upon to advise and to superintend engineering works; nor did they confine themselves to the construction of preventive works, but thoroughly investigated the condition pertaining to fluids at rest or in motion, and gave to the world a valuable series of works on hydraulics and hydraulic engineering, which form the basis of our knowledge of these subjects at the present day.

Some of the best scientific works (prior to the nineteenth century) on engineering subjects we owe to Italian and French writers. The writings of Belidor, an officer of artillery in France in the seventeenth century, who did not, however, confine himself to military subjects, drew attention to engineering questions. Not long after their appearance, the Ponts et Chausées[6] were established, which has maintained ever since a body of able men specially educated for, and devoted to, the prosecution of indus trial works.

The impulse given to road-making in the early part of the last century soon extended to canals and means for facilitating locomotion and transport generally. Tramways were used in connection with mines at least as early as the middle of the seventeenth century, but the rails were, in those days, of wood. The first iron rails are said to have been laid in this country as early as 1738; after which time their use was gradually extended, until it became general in mining districts.

By the beginning of this century the great ports of England were connected by a system of canals; and new harbour works became necessary, and were provided to accommodate the increase of commerce and trade, which improved means of internal transport had rendered possible. It was in the construction of these works that our own Brindley and Smeaton, Telford and Rennie, and other engineers of their time, did so much.

But it was not until the steam-engine, improved and almost created by the illustrious Watt, became such a potent instrument, that engineering works to the extent they have since been carried out became possible or necessary. It gave mankind no

1 Seeman, p. 82.
2 Erskine's "Western Pacific," p. 355.
3 Markham's "Cieza" (note), p. 236.
4 North Holland Canal, finished in 1825.
5 Galileo, b. 1564; Torricelli, b. 1608.
6 Ponts et Chaussées, established 1720.

new faculty, but it at once set his other faculties on an eminence, from which the extent of his future operations became almost unlimited.

Water-mills, wind-mills, and horse-machines were in most cases superseded. Deep mines, before only accessible by adits and water levels, could at once be reached with ease and economy. Lakes and fens which, but for the steam-engine, would have been left untouched, were drained and cultivated.

The slow and laborious toil of hands and fingers, bone and sinew, was turned to other employments, where, aided by ingenious mechanical contrivances, the produce of one pair of hands was multiplied a thousand-fold, and their cunning extended until results marvellous, if you consider them, were attained. Since the time of Watt the steam-engine has exerted a power, made conquests, and increased and multiplied the material interests of this globe to an extent which it is scarcely possible to realise.

But while Watt has gained a world-wide, well-earned fame, the names of those men who have provided the machines to utilise the energies of the steam-engine are too often forgotten. Of their inventions the majority of mankind know little. They worked silently at home, in the mill, or in the factory, observed by few. Indeed, in most cases these silent workers had no wish to expose their work to public gaze. Were it not so, the factory and the mill are not places where people go to take the air. How long in the silent night the inventors of these machines sat and pondered; how often they had to cast aside some long-sought mechanical movement and seek another and a better arrangement of parts, none but themselves could ever know. They were unseen workers, who succeeded by rare genius, long patience, and indomitable perseverance.

More ingenuity and creative mechanical genius is perhaps displayed in machines used for the manufacture of textile fabrics than by those used in any other industry. It was not until late in historical times that the manufacture of such fabrics became established on a large scale in Europe. Although in China man was clothed in silk long ago, and although Confucius, in a work written 2,300 years ago, orders with the greatest minuteness the rules to be observed in the production and manufacture of silk, yet it was worth nearly its weight in gold in Europe in the time of Aurelian, whose empress had to forego the luxury of a silk gown on account of its cost?[1] Through Constantinople and Italy the manufacture passed slowly westwards, and was not established in France until the sixteenth century, and arrived at a still later period in this country. It is related that James V. had to borrow a pair of silk hose from the Earl of Mar, in order that he might not, as he expressed it, appear as a scrub before strangers.

So cotton, of which the manufacture in India dates from before historical times, had scarcely by the Christian era reached Persia and Egypt. Spain in the tenth and Italy in the fourteenth century manufactured it, but Manchester, which is now the great metropolis of the trade, not until the latter half of the seventeenth century.

Linen was worn by the old Egyptians, and some of their linen mummy cloths surpass in fineness any linen fabrics made in later days.[2] The Babylonians wore linen also and wool, and obtained a widespread fame for skill in workmanship and beauty in design.

In this country wool once formed the staple for clothing. Silk was the first rival, but its costliness placed it beyond the reach of the many. To introduce a new material or improved machine into this or other countries a century or more ago was no light undertaking. Inventors, and would-be benefactors alike, ran the risk of loss of life. Loud was the outcry made in the early part of the eighteenth century against the introduction of Indian cottons and Dutch calicoes.

Until 1738, in which year the improvements in spinning machinery were begun, each thread of worsted or cotton wool had been spun between the fingers in this and all other countries. Wyatt, in 1738, invented spinning by rollers instead of fingers, and his invention was further improved by Arkwright. In 1770 Hargreaves patented the spinning jenny, and Crompton the mule in 1775, a machine which combined the advantages of the frames of both Hargreaves and Arkwright. In less than a century after the first invention by Wyatt, double mules were working in Manchester with over 2,000 spindles. Improvements in machines for weaving were begun at an earlier date. In 1579 a ribbon loom is said to have been invented at Dantzic, by which from four to six pieces could be woven at one time, but the machine was destroyed and the inventor lost his life.[1] In 1800 Jacquard's most ingenious invention was brought into use, which, by a simple mechanical operation, determines the movements of the threads which form the pattern in weaving. But the greatest discovery in the art of weaving was wrought by Cartwright's discovery of the power loom, which led eventually to the substitution of steam for manual labour, and enabled a boy with a steam loom to do fifteen times the work of a man with a hand loom.

For complex ingenuity few machines will compare with those used in the manufacture of lace and bobbin net. Hammond, in 1768, attempted to adapt the stocking frame to this manufacture, which had hitherto been conducted by hand. It remained for John Heathcoat to complete the adaptation in 1809, and to revolutionise this branch of industry, reducing the cost of its produce to one-fortieth of what the cost had been before Heathcoat's improvements were effected.

Most of these ingenious machines were in use before Watt's genius gave the world a new motive power in the steam-engine; and, had the steam-engine never been perfected, they would still have enormously increased the productive power of mankind. Water power was applied to many of them; in the first silk-thread mill erected at Derby in 1738, 318 million yards of silk thread were spun daily with one water-wheel.

These are happier times for inventors: keen competition among manufacturers does not let a good invention lie idle now. That which was rejected by old machines as waste is now worked up into useful fabrics by new ones. From all parts of the world new products come—jute from India, flax from New Zealand, and many others which demand new adaptations of old machines or new and untried mechanical arrangements to utilise them. Time would fail me if I were to attempt to enumerate one tithe of these rare combinations of mechanical skill; and, indeed, no one will ever appreciate the labour and supreme mental effort required for their construction who has not himself seen them and their wondrous achievements.

Steamboats, the electric telegraph, and railways, are more within the cognisance of the world at large, and the progress that has been made in them in little more than one generation is better known and appreciated.

It is not more than forty years since one of our scientific men, and an able one too, declared at a meeting of this Association that no steamboat would ever cross the Atlantic; founding his statement on the impracticability, in his view, of a steamboat carrying sufficient coal, profitably, I presume, for the voyage. Yet, soon after this statement was made, the *Sirius* steamed from Bristol to New York in seventeen days,[2] and was soon followed by the *Great Western*, which made the homeward pasage in thirteen-and-a-half days; and with these voyages the era of steamboats began. Like most important inventions, that of the steamboat was a long time in assuming a form capable of being profitably utilised; and even when it had assumed such a form, the objections of commercial and scientific men had still to be overcome.

Among the many names connected with the early progress in the construction of steamboats, perhaps none is more worthy of remembrance than that of Patrick Miller, who, with the assistance of Symington, an engineer, and Taylor, who, was his children's tutor, constructed a small steamboat. Shortly afterwards Lord Dundas, who saw the value of the application of steam for the propulsion of boats, had the first really practical steamboat constructed with a view to using it on the Forth and Clyde Canal. The proprietors, however, objected, and the boat lay idle. Again another attempt to make practical use of the steamboat failed through the death of the Duke of Bridgewater, who, with his characteristic foresight, had seen the value of steam as a motive power for boats, and had determined to introduce steamboats on the canal which bears his name.

The increase in the number of steamboats since the time when the *Sirius* first crossed the Atlantic has been very great. Whereas in 1814 the United Kingdom only possessed two steam vessels, of together 456 tons burden, in 1872 there were on the register of the United Kingdom 3,662 steam vessels, of which the registered tonnage amounted to over a million and a half of tons,[3] or to nearly half the whole steam tonnage of the world, which did not at that time greatly exceed three million tons.

As the number of steamboats has largely increased, so also

1 Manufacture of silk brought from China to Constantinople A.D. 522.
2 Wilkinson's "Ancient Egyptians;" Pliny, bk. xix. c. ii.

1 Beckman's "History of Inventions," vol. ii. p. 528.
2 First steamer crossed the Atlantic by steam alone in 1838.
3 Board of Trade Return, 15th of July, 1874, Table 8.

gradually has their size increased until it culminated in the hands of Brunel in the *Great Eastern*.

A triumph of engineering skill in ship-building, the *Great Eastern* has not been commercially so successful. In this, as in many other engineering problems, the question is not how large a thing can be made, but how large, having regard to other circumstances, it is proper at the time to make it.

If, as regards the dimensions of steamboats, we have at present somewhat overstepped the limits in the *Great Eastern*, much still remains to be done in perfecting the form of vessels, whether propelled by steam or driven by the force of the wind. A distinguished member of this Association, Mr. Froude, has now for some years devoted himself to investigations carried on with a view to ascertain the form of vessel which will offer the least resistance to the water through which it must pass. So many of us in these days are called upon to make journeys by sea as well as by land, that we can well appreciate the value of Mr. Froude's labours, so far as they tend to curtail the time which we must spend on our ocean journeys; and we should all feel grateful to him if from another branch of his investigations, which relates to the rolling of ships, it should result that the movement in passenger vessels could be reduced. A gallant attempt in this direction has lately been made by Mr. Bessemer; whether a successful one yet remains to be proved. In any event, he and those who have acted with him deserve our praise for an experiment which must add to our knowledge.

It is a question of vital importance to the steamboat that the consumption of fuel should be reduced to the smallest possible amount, inasmuch as each ton of fuel excludes a ton of cargo.

As improvements in the form of the hull are effected, less power—that is, less fuel—will be required to propel the vessel through the water for a given distance. Great as have been the improvements effected in marine engines to this end, much still remains to be done. Wolf's compound engine, so long overlooked, is, with some improvements, being at last applied. Whereas the consumption of fuel in such vessels as the *Himalaya* used to be from 5 to 6lbs. of fuel per effective horse-power, it has been reduced, by working steam more expansively in vessels of a later date, to 2 lbs. Yet, comparing this with the total amount of energy of 2 lbs. of coal, it will be found that not a tenth part of the power is obtained which that amount of coal would theoretically call into action.[1]

We live in an age when great discoveries are made, and when they are speedily taken advantage of if they are likely to be of service to mankind.

In former times man's inventions were frequently in advance of the age, and they were laid aside to await a happier era. There were in those earlier days too few persons who cared to, or who could, avail themselves of the proffered boon, and there was no sufficient accumulation of wealth to justify its being appropriated to schemes which are always in their early stage more or less speculative.

There is no more remarkable instance of the rapid utilisation of what was in the first instance regarded by most men as a mere scientific idea, than the adoption and extension of the electric telegraph.

Those who read Odier's letter written in 1773, in which he made known his idea of a telegraph which would enable the inhabitants of Europe to converse with the Emperor of Mogul, little thought that in less than a century a conversation between persons at points so far distant would be possible. Still less did those who saw in the following year messages sent from one room to another by Lesage in the presence of Friedrich of Prussia, realise that they had before them the germ of one of the most extraordinary inventions among the many that will render this century famous.

I should weary you were I to follow the slow steps by which the electric telegraph of to-day was brought to its present state of efficiency. In the present century few years have passed without new workers appearing in the field; some whose object was to utilise the new-found power for the benefit of mankind, others—and their work was not the least important in the end—whose object was to investigate magnetism and electrical phenomena as presenting scientific problems still unsolved. Galvani, Volta, Oersted, Arago, Sturgeon, and Faraday, by their labours, helped to make known the elements which rendered it possible to construct the electric telegraph. With the battery, the electric coil, and the electro-magnet, the elements were complete, and it only remained for Sir Charles Wheatstone and others to combine them in a useful and practically valuable form. The inventions of Alexander, Steinheil, and those of similar nature to that of Sir Charles Wheatstone, were made known at a later date in the same year, which will ever be memorable in the annals of telegraphy.[1]

The first useful telegraph was constructed upon the Blackwall Railway in 1838, Messrs. Wheatstone's and Cooke's instruments being employed. From that time to this the progress of the electric telegraph has been so rapid, that at the present time, including land lines and submarine cables, there are in use in different parts of the world not less than 400,000 miles of telegraph.

Among the numerous inventions of late years, the automatic telegraph of Mr. Alexander Bain, of Dr. Werner Siemens, and of Sir Charles Wheatstone, are especially worthy of notice. Mr. Bain's machine is chiefly used in the United States, that of Dr. Werner Siemens in Germany. In this country the machine invented by Sir Charles Wheatstone, to whom telegraphy owes so much, is chiefly employed. By his machine, after the message has been punched out in a paper ribbon by one machine on a system analogous to the dot and dash of Morse, the sequence of the currents requisite to transmit the message along the wire is automatically determined in a second machine by this perforated ribbon. This second operation is analogous to that by which in Jacquard's loom the motions of the threads requisite to produce the pattern is determined by perforated cards. By Wheatstone's machine errors inseparable from manual labour are avoided; and what is of even more importance in a commercial point of view, the time during which the wire is occupied in the transmission of a message is considerably diminished.

By the application of these automatic systems to telegraphy, the speed of transmission has been wonderfully accelerated, being equal to 200 words a minute, that is, faster than a shorthand writer can transcribe; and, in fact, words can now be passed along the wires of land lines with a velocity greater than can be dealt with by the human agency at either end.

Owing partly to the retarding effects of induction and other causes, the speed of transmission by long submarine cables is much smaller. With the cable of 1858 only 2½ words per minute were got through. The average with the Atlantic cable, Dr. C. W. Siemens informs me, is now seventeen words, but twenty-four words per minute can be read.

One of the most striking phenomena in telegraphy is that known as the duplex system, which enables messages to be sent from each end of the same wire at the same time. This simultaneous transmission from both ends of a wire was proposed in the early days of telegraphy, but, owing to imperfect insulation, was not then found to be practicable; but since then telegraphic wires have been better insulated, and the system is now becoming of great utility, as it nearly doubles the capacity for work of every wire.

And yet within how short a period of time has all the wonderful progress in telegraphy been achieved! How incredulous the world a few years ago would have been if then told of the marvels which in so short a space of time were to be accomplished by its agency!

It is not long ago—1823—that Mr. (now Sir Francis) Ronald, one of the early pioneers in this field of science, published a description of an electric telegraph. He communicated his views to Lord Melville, and that nobleman was obliging enough to reply that the subject should be inquired into; but before the nature of Sir Francis Ronald's suggestions could be known,

[1] Theoretical Energy of 1 lb. of Coal:—
The proportions of heat expended in generating saturated steam at 212° Fahr., and at 14·7 lbs. pressure per square inch, from water at 212° are:—

| | Units of heat. | Mechanical equivalent in foot lbs. |
|---|---|---|
| I. In the formation of steam ... ... | 892·8 | 689,242 |
| II. In resisting the incumbent pressure of 14·7 lbs. per square inch ... | 72·3 | 55,815 |
| | 965.1 | 745,057 |

One pound of Welsh coal will theoretically evaporate 15 lbs. of water at 212° to steam at 212°. Therefore, the full theoretical value of the combustion of 2 lbs. of Welsh coal is—

$$2 \times 15 \times 745{,}057 \text{ foot pounds,}$$

or,

$$\frac{2 \times 15 \times 745{,}057}{60 \times 33{,}000} \text{ horse-power, if consumed in 1 hour.}$$

$$= 11·2 \text{ horse-power.}$$

As the consumption of coal per effective horse-power in a marine engine is 2 lbs., the power obtained is to the whole theoretical power as 1 is to 11.

[1] Dates of patents: Wheatstone, March 1, 1837; Alexander, April 22, 1837; Steinheil, July 1, 1837; Morse, October 1837.

except to a few, that gentleman received a reply from Mr. Barrow, "that telegraphs of any kind were then wholly unnecessary, and that no other than the one then in use would be adopted;" the one then in use being the old semaphore, which, crowning the tops of hills between London and Portsmouth, seemed perfection to the Admiralty of that day.

I am acquainted with some who, when the first Transatlantic cable was proposed, contributed towards that undertaking with the consciousness that it was only an experiment, and that subscribing to it was much the same thing as throwing their money into the sea. Much of this cable was lost in the first attempt to lay it; but its promoters, nothing daunted, made 900 miles more cable, and finally laid it successfully in the following year, 1858.

The telegraphic system of the world comprises almost a complete girdle round the earth; and it is probable that the missing link will be supplied by a cable between San Francisco in California and Yokohama in Japan.

How resolute and courageous those who engaged in submarine telegraphy have been will appear from the fact that, though we have now 50,000 miles of cable in use, to get at this result nearly 70,000 miles were constructed and laid. This large percentage of failure, in the opinion of Dr. C. W. Siemens (to whom I am much indebted for information on this subject), was partly due to the late introduction of testing a cable under water before it is laid, and to the use of too light iron sheathing.

Of immense importance in connection with the subsequent extension of submarine cables have been the discoveries of Ohm and Sir William Thomson, and the knowledge obtained that the resistance in wire of homogeneous metal is directly proportional to the length, so that the place of a fault in a cable of many thousand miles in length can be ascertained with so much precision as to enable you to go at once to repair it, although the damaged cable may lie in some thousands of fathoms of water.

Of railways the progress has been enormous, but I do not know that in a scientific point of view a railway is so marvellous in its character as the electric telegraph. The results, however, of the construction and use of railways are more extensive and widespread, and their utility and convenience brought home to a larger portion of mankind. It has come to pass, therefore, that the name of George Stephenson has been placed second only to that of James Watt; and as men are and will be estimated by the advantages which their labours confer on mankind, he will remain in that niche, unless indeed some greater luminary should arise to outshine him. The merit of George Stephenson consisted, among other things, in this, that he saw more clearly than any other engineer of his time the sort of thing that the world wanted, and that he persevered in despite of learned objectors with the firm conviction that he was right and they were wrong, and that there was within himself the power to demonstrate the accuracy of his convictions.

Railways are a subject on which I may (I hope without tiring you) speak somewhat more at length. The British Association is peripatetic, and without railways its meetings, if held at all, would, I fear, be greatly reduced in numbers. Moreover, you have all an interest in them: you all demand to be carried safely, and you insist on being carried fast. Besides, everybody understands, or thinks he understands, a railway, and therefore I shall be speaking on a subject common to all of us, and shall possibly only put before you ideas which others as well as myself have already entertained.

We who live in these days of roads and railways, and can move with a fair degree of comfort, speed, and safety, almost where we will, can scarcely realise the state of England two centuries ago, when the years of opposition which preceded the era of coaches began; when, as in 1662, there were but six stages in all England, and John Crossdell, of the Charterhouse, thought there were six too many; when Sir Henry Herbert, a member of the House of Commons, could say, "If a man were to propose to carry us regularly to Edinburgh in coaches in seven days, and bring us back in seven more, should we not vote him to Bedlam?"

In spite of short-sighted opposition, coaches made their way; but it was not till a century later, in 1784—and then I believe it was in this city of Bristol—that coaches were first established for the conveyance of mails. Those here who have experienced, as I have, what the discomforts were of long journeys inside the old coaches, will agree with me that they were very great; and I believe, if returns could be obtained of the accidents which happened to coaches, it would be found that many more people were injured and killed in proportion to the number that travelled by that mode than by the railways of to-day.

No sooner had our ancestors settled down with what comfort was possible in their coaches, well satisfied that twelve miles an hour was the maximum speed to be obtained or that was desirable, than they were told that steam conveyance on iron railways would supersede their "present pitiful" methods of conveyance. Such was the opinion of Thomas Gray, the first promoter of railways, who published his work on a general iron railway in 1819. Gray was looked on as little better than a madman. "When Gray first proposed his great scheme to the public," said Chevalier Wilson, in a letter to Sir Robert Peel in 1845, "people were disposed to treat it as an effusion of insanity." I shall not enter on a history of the struggles which preceded the opening of the first railway. They were brought to a successful issue by the determination of a few able and far-seeing men. The names of Thomas Gray and Joseph Sandars, of William James and Edward Pease, should always be remembered in connection with the early history of railways, for it was they who first made the nation familiar with the idea. There is no fear that the name of Stephenson will be forgotten, whose practical genius made the realisation of the idea possible.

The Stockton and Darlington Railway was opened in 1825, the Liverpool and Manchester Railway in 1830, and in the short time which has since elapsed, railways have been extended to every quarter of the globe. No nation possessing wealth and population can afford to be without them; and though at present in different countries there is in the aggregate about 160,000 miles of railway, it is certain that in the course of a very few years this quantity, large as it is, will be very greatly exceeded.

Railways add enormously to the national wealth. More than twenty-five years ago it was proved to the satisfaction of a committee of the House of Commons, from facts and figures which I then adduced, that the Lancashire and Yorkshire Railway, of which I was the engineer, and which then formed the principal railway connection between the populous towns of Lancashire and Yorkshire, effected a saving to the public using the railway of more than the whole amount of the dividend which was received by the proprietors. These calculations were based solely on the amount of traffic carried by the railway, and on the difference between the railway rate of charge and the charges by the modes of conveyance anterior to railways. No credit whatever was taken for the saving of time, though in England preeminently time is money.

Considering that railway charges on many items have been considerably reduced since that day, it may be safely assumed that the railways in the British Islands now produce, or rather save to the nation, a much larger sum annually than the gross amount of all the dividends payable to the proprietors, without at all taking into account the benefit arising from the saving in time. The benefits under that head defy calculation, and cannot with any accuracy be put into money; but it would not be at all over-estimating this question to say that in time and money the nation gains at least what is equivalent to 10 per cent. on all the capital expended on railways. I do not urge this on the part of railway proprietors, for they did not embark in these undertakings with a view to the national gain, but for the expected profit to themselves. Yet it is as well it should be noted, for railway proprietors appear sometimes by some people to be regarded in the light of public enemies.

It follows from these facts that whenever a railway can be made at a cost to yield the ordinary interest of money, it is in the national interest that it should be made. Further, that though its cost might be such as to leave a smaller dividend than that to its proprietors, the loss of wealth to so small a section of the community will be more than supplemented by the national gain, and therefore there may be cases where a Government may wisely contribute in some form to undertakings which, without such aid, would fail to obtain the necessary support.

And so some countries, Russia for instance, to which improved means of transport are of vital importance, have wisely, in my opinion, caused lines to be made which, having regard to their own expenditure and receipts, would be unprofitable works, but in a national point of view are or speedily will be highly advantageous.

The Empire of Brazil, which I have lately visited, is arriving at the conclusion, which I think not an unwise one, that the State can afford, and will be benefited in the end, by guaranteeing 7 per cent. upon any railway that can of itself be shown to produce a net income of 4 per cent., on the assumption that the nation will be benefited at least to the extent of the difference.

A question more important probably in the eyes of many—safety of railway travelling—may not be inappropriate. At all

events, it is well that the elements on which it depends should be clearly understood. It will be thought that longer experience in the management of railways should go to ensure greater safety, but there are other elements of the question which go to counteract this in some degree.

The safety of railway travelling depends on the perfection of the machine in all its parts, including the whole railway, with its movable plant, in that term; it depends also on the nature and quantity of traffic, and lastly, on human care and attention.

With regard to what is human, it may be said that so many of these accidents as arise from the fallibility of men will never be eliminated until the race be improved.

The liability to accident will also increase with the speed, and might be reduced by slackening that speed. It increases with the extent and variety of the traffic on the same line. The public, I fear, will rather run the risk than consent to be carried at a slower rate. The increase in extent and variety of traffic is not likely to receive any diminution; on the contrary, it is certain to augment.

I should be sorry to say that human care may not do something, and I am not among those who object to appeals through the press, and otherwise, to railway companies, though sometimes perhaps they may appear in an unreasonable form. I see no harm in men being urged in every way to do their utmost in a matter so vital to many.

A question may arise whether, if the railways were in the hands of the Government, they could not be worked with greater safety. Government would not pay their officers better, or perhaps so well, as the companies do, and it is doubtful whether they would succeed in attracting to the service abler men. They might do the work with a smaller number of chief officers, for much of the time of the companies' managers is occupied in internecine disputes. They might handle the traffic more despotically, diminishing the number of trains, or the accommodation afforded by them, or in other ways, to ensure more safety; but would the public bear any curtailment of convenience?

One thing they could, and perhaps would do. In cases where the traffic is varied, and could more safely be conducted with the aid of relief lines, which hold out no sufficient inducement to the companies to make, the Government, being content with a lower rate of interest, might undertake to make them, though then comes the question whether, when the whole of this vast machine came to depend for supplies on annual votes of Parliament, money would be forthcoming in greater abundance than it is under the present system.

But the consideration of this subject involves other and more difficult questions.

Where are the labours of Government to stop? The cares of State which cannot be avoided are already heavy and will grow heavier every year. Dockyard establishments are trifling to what the railway establishments, which already employ 250,000 men, would be. The assumption of all the railways would bring Government into conflict with every passenger, every trader, and every manufacturer. With the railway companies there would be no difficulty; they would sell their undertakings to anyone, provided the price was ample.

Looking at the vast growth of railway traffic, one measure occurs to me as conducive to the safety of railway passengers, and likely to be demanded some day; it is to construct between important places railways which should carry passengers only or coals only, or be set apart for some special separation of traffic; though there will be some difficulty in accomplishing this. Landowners, through whose properties such lines would pass, would probably wish to use such lines for general purposes. Nevertheless, it may have to be tried some day.

It would be instructive, were it practicable, to compare the relative proportion of accidents by railway and by the old stage-coaches, but no records that I am aware of exist of the latter that would enable such a comparison to be made. It is practicable to make some sort of comparison between the accidents in the earlier day of our own railways and the accidents occurring at a ater date

The Board of Trade have unfortunately abandoned the custom, which they adopted from 1852 to 1859, of returning the passenger mileage, which is given in the German returns, and is the proper basis upon which to found the proportion of accidents, and not on the number of passengers without any regard to distance travelled, which has altered very much, the average journey per passenger being nearly half in 1873 what it was in 1846.

It would be erroneous to compare the proportions of accidents to passengers carried in various years, even if the correct number of passengers travelling were given. But a figure is always omitted from the Board of Trade return, which makes the proportion of accidents to passengers appear larger than it is; this is the number of journeys performed by season-ticket holders. Some estimate could be made of the journeys of season-ticket holders by dividing the receipts by an estimated average fare, or the companies could make an approximate estimate, and the passenger mileage could be readily obtained by the railway companies from the tickets. These additions would greatly add to the value of the railway returns as statistical documents, and render the deductions made from them correct.

Though it has been a work of labour, I have endeavoured to supply these deficiencies, and I believe the results arrived at may be taken as fairly accurate.[1]

From the figures so arrived at, it appears the passenger mileage has doubled between 1861 and 1873; and at the rate of increase between 1870 and 1873 it would become double what it was in 1873 in twelve years from that time, namely in 1885.

The number of passengers has doubled between 1864 and 1873, and at the rate of increase between 1870 and 1873 it would become double what it was in 1873 in eleven-and-a-half years, or in 1885.

It must, however, be remembered that the rate of increase since 1870, though very regular for 1871, 1872, and 1873, is greater than in previous years, being probably due to the rise of wages and the great development of third-class traffic, and it would not be safe to assume this rate of increase will continue.

Supposing no improvement had been effected in the working of railway traffic, by the interlocking of points, the block system, &c., the increase of accidents should have borne some proportion to the passenger mileage, multiplied by the proportion between the train mileage and the length of line open, as the number of trains passing over the same line of rails would tend to multiply accidents in an increasing proportion, especially where the trains run at different speeds.

The number of accidents varies considerably from year to year, but taking two averages of ten years each, it appears that the proportion of deaths of passengers from causes beyond their control to passenger miles travelled in the ten years ending December 31, 1873, was only two-thirds of the same proportion in the ten years ending December 31, 1861; the proportion of all accidents to passengers from causes beyond their own control was one-ninth more in the last ten years than in the earlier, whereas the frequency of trains had increased on the average one-fourth.

The limit, however, of considerable improvements in signalling, increased brake power, &c., will probably be reached before long, and the increase of accidents will depend on the increase of traffic, together with the increased frequency of trains.

The large growth of railway traffic, which we may assume will double in twenty years, will evidently greatly tax the resources of the railway companies; and unless the present companies increase the number of the lines of way, as some have commenced to do, or new railways are made, the system of expeditious and safe railway travelling will be imperilled. Up to the present time, however, the improvements in regulating the traffic appear to have kept pace with the increase of traffic and of speed, as the slight increase in the proportion of railway accidents to passenger miles is probably chiefly due to a larger number of trifling bruises being reported now than formerly.

I believe it was a former President of the Board of Trade who said to an alarmed deputation, who waited upon him on the subject of railway travelling, that he thought he was safer in a railway carriage than anywhere else.

If he gave any such opinion he was not far wrong, as is sufficiently evident when it can be said that there is only one passenger injured in every four million miles travelled, or that, on an average, a person may travel 100,000 miles each year for forty years, and the chances be slightly in his favour of his not receiving the slightest injury.

A pressing subject of the present time is the economy of fuel. Members of the British Association have not neglected this momentous question.

At the meeting held at Newcastle-on-Tyne in 1863, Sir William Armstrong sounded an alarm as to the proximate exhaustion of our coal-fields.

Table on opposite page

Mr. Bramwell, when presiding over the Mechanical Section at Brighton, drew attention to the waste of fuel.

Dr. Siemens, in an able lecture he delivered by request of the Association to the operative classes at the meeting at Bradford, pointed out the waste of fuel in special branches of the iron trade, to which he has devoted so much attention.

He showed on that occasion that, in the ordinary re-heating furnace, the coal consumed did not produce the twentieth part of its theoretical effect, and in melting steel in pots in the ordinary way not more than one-seventieth part; in melting one ton of steel in pots about $2\frac{1}{2}$ tons of coke being consumed. Dr. Siemens further stated that, in his regenerative gas furnace, one ton of steel was melted with 12 cwt. of small coal.

Mr. Lowthian Bell, who combines chemical knowledge with the practical experience of an ironmaster, in his Presidential address to the members of the Iron and Steel Institute in 1873, stated that, with the perfect mode of withdrawing and utilising the gases and the improvement in the furnaces adopted in the Cleveland district, the present make of pig-iron in Cleveland is produced with $3\frac{1}{2}$ million tons of coal less than would have been needed fifteen years ago; this being equivalent to a saving of 45 per cent. of the quantity formerly used. He shows by figures, with which he has favoured me, that the calorific power of the waste gases from the furnaces is sufficient for raising all the steam and heating all the air the furnaces require.

It has already been stated that by working steam more expansively, either in double or single engines, the consumption of fuel in improved modern engines compared with the older forms may be reduced to one-third.

All these reductions still fall far short of the theoretical effect of fuel which may be never reached. Mr. Lowthian Bell's figures go to show that in the interior of the blast furnace, as improved in Cleveland, there is not much more to be done in reducing the consumption of fuel; but much has already been done, and could the reductions now attainable, and all the information already acquired be universally applied, the saving in fuel would be enormous.

How many open blast furnaces still belch forth flame and gas and smoke as uselessly, and with nearly as much mischief to the surrounding neighbourhood, as the fires of Etna or Vesuvius? How many of the older and more extravagant forms of steam-engine still exist?

What is to be done with the intractable householder, with the domestic hearth, where, without going to German stoves, but by using Galton's grates and other improvements, everything necessary both for comfort and convenience could be as well attained with a much smaller consumption of coal?

If I have pointed out that we do not avail ourselves of more than a fractional part of the useful effects of fuel, it is not that I expect we shall all at once mend our ways in this respect. Many cases of waste arise from the existence of old and obsolete machines, of bad forms of furnaces, of wasteful grates, existing in most dwelling-houses; and these are not to be remedied at once, for not everyone can afford, however desirable it might be, to cast away the old and adopt the new.

In looking uneasily to the future supply and cost of fuel, it is, however, something to know what may be done even with the application of our present knowledge; and could we apply it universally to-day, all that is necessary for trade and comfort could probably be as well provided for by one-half the present consumption of fuel; and it behoves those who are beginning to build new mills, new furnaces, new steamboats, or new houses, to act as though the price of coal which obtained two years ago had been the normal and not the abnormal price.

There was in early years a battle of the gauges, and there is now a contest about guns; but your time will not permit me to say much on their manufacture.

Here again the progress made in a few years has been enormous; and in contributing to it, two men, Sir Wm. Armstrong and Sir Joseph Whitworth, both civil engineers, in this country at all events, deservedly stand foremost. The iron coil construction of Sir William Armstrong has already produced remarkable and satisfactory results; in discussing further possible improvements, the question is embarrassed by attempting to draw sharp lines between what is called steel and iron.

There is nothing that I can see to limit the size of guns, except the tenacity and endurance of the metal, whatever we may choose to call it, of which they are to be made.

Sir Joseph Whitworth, who has already done more than any other man in his department to secure good workmanship, and whose ideal of perfection is ever expanding, has long been seeking, and not without success, by enormous compression, to increase those qualities in what he calls homogeneous metal. Make the metal good enough, and call it iron if you will, and the size of a gun may be anything: the mere construction and handling of a gun of 100 tons, or of far greater weight, with suitable mechanical appliances, presents no difficulty.

Relying on the qualities of his compressed metal, Sir Joseph is now seeking by a singular experiment to limit the travel of the recoil, as far as practicable, to the elasticity of the metal. By

RAILWAY ACCIDENTS.—*Great Britain and Ireland.*

| Year. | Proportion of train mileage for year to total length of single line of way, excluding sidings. | Number of accidents to passenger trains. | Average journey of passengers of all classes, exclusive of periodical ticket-holders. | Number of accidents to passengers from causes beyond their control. Killed. | Injured. | Total. | Number of miles travelled by passengers of all classes, including periodical ticket-holders. | Proportion of passengers killed from causes beyond their control to passenger miles travelled. | Proportion of passengers injured or killed from causes beyond their control to passenger miles travelled. | Proportion of passengers killed from causes beyond their control to passenger journeys. | Proportion of passengers injured or killed from causes beyond their control to passenger journeys. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. | X. | XI. | XII. |
| | (*a*) | No. | miles. | No. | No. | No. | (*b*) miles. | (*c*) miles. | (*d*) miles. | (*e*) No. | (*f*) No. |
| 1846 | | 51 | 18·80 | 5 | 146 | 151 | 894,573,000 | 1 in 178,915,000 | 1 in 5,924,000 | 1 in 9,514,000 | 1 in 315,000 |
| 1849 | | 33 | 18·21 | 5 | 84 | 89 | 1,162,806,000 | 1 in 232,561,000 | 1 in 13,065,000 | 1 in 12,768 000 | 1 in 717,000 |
| 1852 | | 60 | 16·19 | 10 | 372 | 382 | 1,473,255,000 | 1 in 147,326,000 | 1 in 3,857,000 | 1 in 8,910 000 | 1 in 241,000 |
| 1855 | 5,134 | 75 | 15·34 | 10 | 311 | 321 | 1,864,175,000 | 1 in 186,418,000 | 1 in 5,807,000 | 1 in 12,316 000 | 1 in 384,000 |
| 1858 | 5,418 | 48 | 14·54 | 25 | 419 | 444 | 2,084,353,000 | 1 in 83,374,000 | 1 in 4,694,000 | 1 in 5,809,000 | 1 in 327,000 |
| 1861 | 5,921 | 55 | 14·21 | 46 | 780 | 826 | 2,547,653,000 | 1 in 55,384,000 | 1 in 3,084,000 | 1 in 3,947,000 | 1 in 220,000 |
| 1864 | 6,395 | 75 | 12·47 | 14 | 697 | 711 | 2,966,592,000 | 1 in 211,899,000 | 1 in 4,172 000 | 1 in 17,141,000 | 1 in 338,000 |
| 1867 | 6,724. | 94 | 11·56 | 19 | 689 | 708 | 3,478,262,000 | 1 in 183,066,000 | 1 in 4,913,000 | 1 in 15,947,000 | 1 in 4 8,000 |
| 1870 | 7,253 | 123 | 10 74 | 65 | 1084 | 1149 | 3,801,734,000 | 1 in 58,488,000 | 1 in 3,309,000 | 1 in 5,465,000 | 1 in 309,000 |
| 1873 | 7,894 | | 10·53 | 38 | 1504 | 1542 | 5,060,329 000 | 1 in 133,167,000 | 1 in 3,282,000 | 1 in 12,683,000 | 1 in 313,000 |
| Average | 1852-61 | (inclusive) | | 20 | 425 | 445 | 2,018,485,000 | 1 in 100,924,000 | 1 in 4,536,000 | 1 in 6,850,000 | 1 in 308,000 |
| Average | 1864-73 | (inclusive) | | 26 | 920 | 946 | 3,826,729,000 | 1 in 147,182,000 | 1 in 4,045 000 | 1 in 13,165,000 | 1 in 362,000 |

(*a*) The figures in this column are obtained by dividing the total train mileage by the aggregate length of single line of way, excluding sidings, and not by the actual length of the railway.

(*b*) The passenger mileage has been calculated, as it is not given in the Board of Trade returns, except partially between 1852 and 1859 (inclusive), and since 1859 no return under this head has been made.

(*c*) The figures in column No. IX. are obtained by dividing those in column VIII. by those in column V.

(*d*) The figures in column X. are obtained by dividing those in column VIII. by those in column VII.

(*e*) The figures in column XI. are obtained by dividing the total number of passengers carried in each year (including a calculated number of journeys made by season ticket holders) by the figures in column V.

(*f*) The figures in column XII. are obtained by dividing the total number of passengers carried in each year by the figures in column VII.

N.B.—The passenger mileage includes the miles estimated to have been travelled by season ticket holders. This estimate was obtained by calculating a average fare per mile for each class of passenger, and dividing the receipts from the season ticket holders by the average fare.

attaching the muzzle of the gun to an outer casing, through which the force of the recoil is carried back to the trunnions, he proposes to avail himself of this elasticity to the extent of one-and-a-half times the length of the gun; whether its elasticity alone in so short a space will suffice without aid is, perhaps, doubtful; but other aid may be applied, and the experiment, whether successful or not, will be interesting.

Docks and harbours I have no time to mention, for it is time this long and, I fear, tedious address, should close.

"Whence and whither," is an aphorism which leads us away from present and plainer objects to those which are more distant and obscure; whether we look backwards or forwards, our vision is speedily arrested by an impenetrable veil.

On the subjects I have chosen you will probably think I have travelled backwards far enough. I have dealt to some extent with the present.

The retrospect, however, may be useful to show what great works were done in former ages.

Some things have been better done than in those earlier times, but not all.

In what we choose to call the ideal we do not surpass the ancients. Poets and painters and sculptors were as great in former times as now; so, probably, were the mathematicians.

In what depends on the accumulation of experience, we ought to excel our forerunners. Engineering depends largely on experience; nevertheless, in future times, whenever difficulties shall arise or works have to be accomplished for which there is no precedent, he who has to perform the duty may step forth from any of the walks of life, as engineers have not unfrequently hitherto done.

The marvellous progress of the last two generations should make everyone cautious of predicting the future. Of engineering works, however, it may be said that their practicability or impracticability is often determined by other elements than the inherent difficulty in the works themselves. Greater works than any yet achieved remain to be accomplished—not perhaps yet awhile. Society may not yet require them; the world could not at present afford to pay for them.

The progress of engineering works, if we consider it, and the expenditure upon them, has already in our time been prodigious. One hundred and sixty thousand miles of railway alone, put into figures at 20,000*l.* a mile, amounts to 3,200 million pounds sterling; add 400,000 miles of telegraph at 100*l.* a mile, and 100 millions more for sea canals, docks, harbours, water and sanitary works constructed in the same period, and we get the enormous sum of 3,340 millions sterling expended in one generation and a half on what may undoubtedly be called useful works.

The wealth of nations may be impaired by expenditure on luxuries and war; it cannot be diminished by expenditure on works like these.

As to the future, we know we cannot create a force; we can, and no doubt shall, greatly improve the application of those with which we are acquainted. What are called inventions can do no more than this, yet how much every day is being done by new machines and instruments.

The telescope extended our vision to distant worlds. The spectroscope has far outstripped that instrument, by extending our powers of analysis to regions as remote.

Postal deliveries were and are great and able organisations, but what are they to the telegraph?

Need we try to extend our vision into futurity farther? Our present knowledge, compared to what is unknown even in physics, is infinitesimal. We may never discover a new force—yet, who can tell?

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## SECTION A.

### MATHEMATICAL AND PHYSICAL.

### OPENING ADDRESS BY THE PRESIDENT, PROF. BALFOUR STEWART.

Since the last meeting of the British Association, science has had to mourn the loss of one of its pioneers, in the death of the veteran astronomer, Schwabe, of Dessau, at a good old age, not before he had faithfully and honourably finished his work. In truth this work was of such a nature that the worker could not be expected long to survive its completion.

It is now nearly fifty years since he first began to produce daily sketches of the spots that appeared upon the sun's surface. Every day on which the sun was visible (and such days are more frequent in Germany than in this country), with hardly any intermission for forty years, this laborious and venerable observer made his sketch of the solar disc. At length this unexampled perseverance met with its reward in the discovery of the periodicity of sun-spots, a phenomenon which very speedily attracted the attention of the scientific world.

It is not easy to over-rate the importance of the step gained when a periodicity was found to rule these solar outbreaks. *A priori* we should not have expected such a phenomenon. If the old astronomers were perplexed by the discovery of sun-spots, their successors must have been equally perplexed when they ascertained their periodicity. For while all are ready to acknowledge periodicity as one of the natural conditions of terrestrial phenomena, yet everyone is inclined to ask what there can be to cause it in the behaviour of the sun himself. Manifestly it can only have two possible causes. It must either be the outcome of some strangely hidden periodical cause residing in the sun himself, or must be produced by external bodies, such as planets, acting somehow in their varied positions on the atmosphere of the sun. But whether the cause be an internal or external one—in either case we are completely ignorant of its nature.

We can easily enough imagine a cause operating from the sun himself and his relations with a surrounding medium to produce great disturbances on his surface, but we cannot easily imagine why disturbances so caused should have a periodicity. On the other hand we can easily enough attach periodicity to any effect caused by the planets, but we cannot well see why bodies comparatively so insignificant should contribute to such very violent outbreaks as we now know sun-spots to be.

If we look within we are at a loss to account for the periodicity of solar disturbances, and if we look without we are equally at a loss to account for their magnitude. But since that within the sun is hidden from our view, it cannot surely be considered blameworthy if astronomers have directed their attention to that without and have endeavoured to connect the behaviour of sun-spots with the positions of the various planets. Stimulated no doubt by the success which had attended the labours of Schwabe, an English astronomer was the next to enter the field of solar research.

The aim of Mr. Carrington was, however, rather to obtain very accurate records of the positions, the sizes, and the shapes of the various sun-spots than to make a very extensive and long-continued series of observations. He was aware that a series at once very accurate and very extended is beyond the power of a private individual, and can only be undertaken by an established institution. Nevertheless, each sun-spot that made its appearance during the seven years extending from the beginning of 1854 to the end of 1860 was sketched by Mr. Carrington with the greatest possible accuracy, and had also its heliographic position, that is to say its solar latitude and longitude, accurately determined.

One of the most prominent results of Mr. Carrington's labours was the discovery of the fact that sun-spots appear to have a proper motion of their own—those nearer the solar equator moving faster than those more remote. Another was the discovery of changes apparently periodical affecting the disposition of spots in solar latitude. It was already known that sun-spots confined themselves to the sun's equatorial regions, but Mr. Carrington showed that the region affected was liable to periodical elongations and contractions, although his observations were not sufficiently extended to determine the exact length of this period.

Before Mr. Carrington had completed his seven' years labours, celestial photography had been introduced by Mr. Warren De la Rue. Commencing with his private observatory, he next persuaded the Kew Committee of the British Association to allow the systematic photography of the sun to be carried on at their observatory under his superintendence, and in the year 1862 the first of a ten years' series of solar photographs was begun. Before this date however Mr. De la Rue had ascertained, by means of his photoheliograph, on the occasion of the total eclipse of 1860, that the red prominences surrounding the eclipsed sun, belong, without doubt, to our luminary himself.

The Kew observations are not yet finally reduced, but already several important conclusions have been obtained from them by Mr. De la Rue and the other Kew observers. In the first place the Kew photographs confirm the theory of Wilson that sun-spots are phenomena, the dark portions of which exist at a level considerably beneath the general surface of the sun; in other words, they are hollows, or pits, the interior of which is of course filled up with the solar atmosphere. The Kew observers were

likewise led to associate the low temperature of the bottom of sun-spots with the downward carriage of colder matter from the atmosphere of the sun, while the upward rush of heated matter was supposed to account for the faculæ or bright patches which almost invariably accompany spots. In the next place the Kew observers, making use not only of the Kew series but of those of Schwabe and Carrington, which were generously placed at their disposal, have discovered traces of the influence of the nearer planets upon the behaviour of sun-spots. This influence appears to be of such a nature that spots attain their maximum size when carried by rotation into positions as far as possible remote from the influencing planet—that is to say into positions where the body of the sun is between them and the planet. There is also evidence of an excess of solar action when two influential planets come near together. But although considerable light has thus been thrown on the periodicity of sun-spots, it ought to be borne in mind that the cause of the remarkable period of eleven years and a quarter, originally discovered by Schwabe, has not yet been properly explained. The Kew observers have likewise discovered traces of a peculiar oscillation of spots between the two hemispheres of the sun, and finally their researches will place at the command of the observers the data for ascertaining whether centres of greater and lesser solar activity are connected with certain heliocentric positions.

While the sun's surface was thus being examined both telescopically and photographically, the spectroscope came to be employed as an instrument of research. It had already been surmised by Prof. Stokes, that the vapour of sodium at a comparatively low temperature forms one of the constituents of the solar atmosphere, inasmuch as the dark line D in the spectrum of the sun coincides in position with the bright line given out by incandescent sodium vapour.

This method of research was greatly extended by Kirchhoff, who soon found that many of the dark lines in the solar spectrum were coincident with the bright lines of sundry incandescent metallic vapours, and a good beginning was thus made towards ascertaining the chemical constitution of the sun.

The new method soon brought forth further fruit when applied in the hands of Huggins, Miller, Secchi, and others, to the more distant heavenly bodies. It was speedily found that the fixed stars had constitutions very similar to that of the sun. But a peculiar and unexpected success was attained when some of the nebulæ were examined spectroscopically. To-day it seems (so rapidly has knowledge progressed) very much like recalling an old superstition to remind you that until the advent of the spectroscope the irresolvable nebulæ were considered to be gigantic and remote clusters of stars, the individual members of which were too distant to be separated from each other even with a telescope like that of Lord Rosse. But Mr. Huggins, by means of the spectroscope, soon found that this was not the case, and that most of the nebulæ which had defied the telescope gave indications of incandescent hydrogen gas. It was also found by this observer that the proper motions of some of the fixed stars in a direction to or from the earth might be detected by means of the displacement of their spectral lines, a method of research which was first enunciated by Fizeau. Hitherto in such applications of the spectroscope, the body to be examined was viewed as a whole. It had not yet been attempted to localise the use of this instrument so as to examine particular districts of the sun, as for instance a sun-spot, or the red flames already proved by De la Rue to belong to our luminary. This application was first made by Mr. Lockyer, who in the year 1865 examined a sun-spot spectroscopically and remarked the greater thickness of the lines in the spectrum of the darker portion of the spot.

Dr. Frankland had previously found that thick spectral lines correspond to great pressure, and hence the inference from the greater thickness of lines in the umbra of a spot is that this umbra or dark portion is subject to a greater pressure; that is to say, it exists below a greater depth of the solar atmosphere than the general surface of the sun. Thus the results derived from the Kew photoheliograph and those derived from the spectroscope were found to confirm each other. Mr. Lockyer next caused a powerful instrument to be constructed for the purpose of viewing spectroscopically the red flames round the sun's border, in the hope that if they consisted of ignited gas the spectroscope would disperse, and thus dilute and destroy the glare which prevents them from being seen on ordinary occasions.

Before this instrument was quite ready these flames had been analysed spectroscopically by Capt. Herschel, M. Janssen, and others, on the occasion of a total eclipse occurring in India, and they were found to consist of incandescent gas, most probably hydrogen. But the latter of these observers (M. Janssen) made the important observation that the bright lines in the spectrum of these flames remained visible even after the sun had reappeared, from which he argued that a solar eclipse is not necessary for the examination of this region.

Before information of the discovery made by Janssen had reached this country, the instrument of Mr. Lockyer had been completed, and he also found that by its means he was able to analyse at leisure the composition of the red flames without the necessity of a total eclipse. An atmosphere of incandescent hydrogen was found to surround our luminary into which, during the greater solar storms, sundry metallic vapours were injected, sodium, magnesium, and iron forming the three that most frequently made their appearance.

Here we come to an interesting chemical question.

It had been remarked by Maxwell and by Pierce as the result of the molecular theory of gases that the final distribution of any number of kinds of gas in a vertical direction under gravity is such that the density of each gas at a given height is the same as if all the other gases had been removed, leaving it alone. In our own atmosphere the continual disturbances prevent this arrangement from taking place, but in the sun's enormously extended atmosphere (if indeed our luminary be not nearly all gaseous) it appears to hold, inasmuch as the upper portion of this atmosphere, dealing with known elements, apparently consists entirely of hydrogen. Various other vapours are, however, as we have seen, injected from below the photosphere into the solar atmosphere on the occasion of great disturbances, and Mr. Lockyer has asked the question, whether we have not here a true indication of the relative densities of these various vapours derived from the relative heights to which they are injected on such occasions.

This question has been asked, but it has not yet received a definite solution, for chemists tell us that the vapour densities of some of the gases injected into the sun's atmosphere on the occasion of disturbances are, as far as they know from terrestrial observations, different from those which would be indicated by taking the relative heights attained in the atmosphere of the sun. Mr. Lockyer has attempted to bring this question a step nearer to its solution by showing that the vapours at the temperatures at which their vapour densities have been experimentally determined are not of similar molecular constitution, whereas in the sun we get an indication, from the fact that all the elements give us line spectra, that they are in similar molecular states.

Without, however, attempting to settle this question, I may remark that we have here an interesting example of how two branches of science—physics and chemistry—meet together in solar research.

It had already been observed by Kirchhoff that sometimes one or more of the spectral lines of an elementary vapour appeared to be reversed in the solar spectrum, while the other lines did not experience reversal. Mr. Lockyer succeeded in obtaining an explanation of this phenomenon. This explanation was found by means of the method of localisation already mentioned.

Hitherto, when taking the spectrum of the electric spark between the two metallic poles of a coil, the arrangements were such as to give an average spectrum of the metal of these poles; but it was found that when the method of localisation was employed, different portions of the spark gave a different number of lines, the regions near the terminals being rich in lines, while the midway regions give comparatively few.

If we imagine that in the midway regions the metallic vapour given off by the spark is in a rarer state than that near the poles, we are thus led to regard the short lines which cling to the poles as those which require a greater density or nearness of the vapour particles before they make their appearance; while on the other hand, those which extend all the way between the two poles come to be regarded as those which will continue to make their appearance in vapour of great tenuity.

Now it was remarked that these long lines were the very lines which were reversed in the atmosphere of the sun. Hence when we observe a single coincidence between a dark solar line and the bright line of any metal, we are further led to inquire whether this bright line is one of the long lines which will continue to exist all the way between two terminals of that metal when the spark passes.

If this be the case, then we may argue with much probability that the metal in question really occurs in the solar atmosphere; but if, on the other hand, the coincidence is merely between a solar dark line and a short bright one, then we are led to imagine that it is not a true coincidence, but something which will

probably disappear on further examination. This method has already afforded us a means of determining the relative amount of the various metallic vapours in the sun's atmosphere. Thus, in some instances all lines are reversed, whereas in others the reversal extends only to a few of the longer lines.

Several new metals have thus been added to the list of those previously detected in the solar atmosphere, and it is now certain that the vapours of hydrogen, potassium, sodium, rubidium, barium, strontium, calcium, magnesium, aluminium, iron, manganese, chromium, cobalt, nickel, titanium, lead, copper, cadmium, zinc, uranium, cerium, vanadium, and palladium occur in our luminary.

I have spoken hitherto only of telescopic spectroscopy; but photography has been found capable of performing the same good service towards the compound instrument consisting of the telescope and its attached spectroscope, which it had previously been known to perform towards the telescope alone. It is of no less importance to secure a permanent record of spectral peculiarities than it is to secure a permanent record of telescopic appearances. This application of photography to spectrum observations was first commenced on a sufficient scale by Mr. Rutherford, of New York, and already promises to be one of the most valuable aids in solar inquiry.

In connection with the spectroscope I ought here to mention the names of Respighi, and Secchi, who have done much in the examination of the solar surface from day to day. It is of great importance to the advancement of our knowledge, that two such competent observers are stationed in a country where the climate is so favourable to continued observation.

The examination of the sun's surface by the spectroscope suggests many interesting questions connected with other branches of science. One of these has already been alluded to. I may mention two others put by Mr. Lockyer, premising, however, that at present we are hardly in a position to reply to them. It has been asked whether the very high temperatures of the sun and of some of the stars may not be sufficient to produce the disassociation of those molecular structures which cannot be disassociated by any terrestrial means; in other words, the question has been raised, whether our so-called elements are really elementary bodies.

A third question is of geological interest. It has been asked whether a study of the solar atmosphere may not throw some light upon the peculiar constitution of the upper strata of the earth's surface, which are known to be of less density than the average interior of our planet.

If we have learned to be independent of total eclipses as far as the lower portions of the solar atmosphere are concerned, it must be confessed that as yet the upper portions—the outworks of the sun—can only be successfully approached on these rare and precious occasions. Thanks to the various Government expeditions despatched by Great Britain, by the United States, and by several Continental nations—thanks, also, to the exertions of Lord Lindsay and other astronomers—we are in the possession of definite information regarding the solar corona.

In the first place, we are now absolutely certain that a large part of this appendage unmistakably belongs to our luminary, and in the next place, we know that it consists, in part at least, of an ignited gas giving a peculiar spectrum, which we have not yet been able to identify with that of any known element. The temptation is great to associate this spectrum with the presence of something lighter than hydrogen, of the nature of which we are yet totally ignorant.

A peculiar physical structure of the corona has likewise been suspected. On the whole, we may say that this is the least known, while it is perhaps the most interesting, region of solar research; most assuredly it is well worthy of further investigation.

If we now turn our attention to matters nearer home, we find that there is a difficulty in grasping the facts of terrestrial meteorology no less formidable than that which assails us when we investigate solar outbreaks. The latter perplex us because the sun is so far away and because also his conditions are so different from those with which we are here familiar; while on the other hand, the former perplex us because we are so intimately mixed up with them in our daily lives and actions; because, in fact, the scale is so large and we are so near. The result has been that until quite recently our meteorological operations have been conducted by a band of isolated volunteers individually capable and skilful, but from their very isolation incapable of combining together with advantage to prosecute a scientific campaign. Of late, however, we have begun to perceive that if we are to make any advance in this very interesting and practical subject, a different method must be pursued, and we have already reaped the first fruits of a more enlightened policy; already we have gained some knowledge of the constitution and habits of our atmosphere.

The researches of Wells and Tyndall have thrown much light on the cause of dew. Humboldt, Dové, Buys Ballot, Jelinek, Quetelet, Hansteen, Kupffer, Forbes, Welsh, Glaisher, and others have done much to give us an accurate knowledge of the distribution of terrestrial temperature. Great attention has likewise been given to the rainfall of Great Britain and Ireland, chiefly through the exertions of one individual, Mr. G. J. Symons.

To Dové we are indebted for the law of rotation of the wind, to Redfield for the spiral theory of cyclones, to Francis Galton for the theory of anti-cyclones, to Buchan for an investigation into the disposition of atmospheric pressure which precedes peculiar types of weather, to Stevenson for the conception of barometric gradients, to Scott and Meldrum for an acquaintance with the disposition of winds which frequently precedes violent outbreaks; and to come to the practical application of laws, we are much indebted to the late Admiral Fitzroy and the system which he greatly helped to establish for our telegraphic warnings of coming storms.

Again, the meteorology of the ocean has not been forgotten. The well-known name of Maury will occur to every one as that of a pioneer in this branch of inquiry. Fitzroy, Leverrier, Meldrum, Toynbee, and others have likewise done much; and it is understood that the meteorological offices of this and other maritime countries are now busily engaged upon this important and practical subject. Finally, the movements of the ocean and the temperatures of the oceanic depths have recently been examined with very great success in vessels despatched by her Majesty's Government; and Dr. Carpenter has by this means been able to throw great light upon the convection currents exhibited by that vast body of water which girdles our globe.

It would be out of place to enter here more minutely into this large subject, and already it may be asked what connection has all this with that part of the address that went before it.

There are, however, strong grounds for supposing that the meteorology of the sun and that of the earth are intimately connected together. Mr. Broun has shown the existence of a meteorological period connected apparently with the sun's rotation; five successive years' observations of the barometer at Singapore all giving the period 25·74 days. Mr. Baxendell, of Manchester, was, I believe, the first to show that the convection currents of the earth appear to be connected somehow with the state of the sun's surface as regards spots; and still more recently, Mr. Meldrum, of the Mauritius Observatory, has shown by a laborious compilation of ships' logs and by utilising the meteorological records of the island, that the cyclones in the Indian Ocean are most frequent in years when there are most sunspots. He likewise affords us grounds for supposing that the rainfall, at least in the tropics, is greatest in years of maximum solar disturbance.

M. Poey has found a similar connection in the case of the West Indian hurricanes; and finally, Piazzi Smyth, Stone, Köppen, and still more recently, Blanford, have been able to bring to light a cycle of terrestrial temperature having apparent reference to the condition of the sun.

Thus, we have strong matter-of-fact grounds for presuming a connection between the meteorology of our luminary and that of our planet, even although we are in complete ignorance as to the exact nature of this bond.

If we now turn to terrestrial magnetism the same connection becomes apparent.

Sir Edward Sabine was the first to show that the disturbances of the magnetism of the earth are most violent during years of maximum sunspots. Mr. Broun has shown that there is likewise a reference in magnetic phenomena to the period of the sun's rotation about his axis, an observation recently confirmed by Hornstein; and still more recently, Mr. Broun has shown that the moon has an action upon the earth's magnetism which is not altogether of a tidal nature, but depends, in part, at least, upon the relative position of the sun and moon.

I must trust to your forbearance if I now venture to bring forward considerations of a somewhat speculative nature.

We are all familiar with the generalisation of Hadley, that is to say we know there are under-currents sweeping along the surface of the earth from the poles to the equator, and upper-currents sweeping back from the equator to the poles. We are

likewise aware that these currents are caused by the unequal temperature of the earth; they are in truth convection-currents, and their course is determined by the positions of the hottest and coldest parts of the earth's surface. We may expect them, therefore, to have a reference not so much to the geographical equator and poles as to the hottest and coldest regions. In fact, we know that the equatorial regions into which the trade winds rush and from which the anti-trades take their origin, have a certain annual oscillation depending upon the position of the sun, or in other words upon the season of the year. We may likewise imagine that the region into which the upper-currents pour themselves is not the geographical pole, but the pole of greatest cold.

In the next place we may imagine that these currents, as far as regards a particular place, have a daily oscillation. This has, I believe, been proved as regards the lower currents or trade-winds which are more powerful during the day than during the night, and we may therefore expect it to hold good with regard to the upper-currents or anti-trades; in fact, we cannot go wrong in supposing that they also, as regards any particular place, exhibit a daily variation in the intensity with which they blow.

Again, we are aware that the earth is a magnet. Let us not now concern ourselves about the origin of its magnetism, but rather let us take it as it is. We must next bear in mind that rarefied air is a good conductor of electricity; indeed, according to recent experiments, an extremely good conductor. The return trades that pass above from the hotter equatorial regions to the poles of cold, consisting of moist rarefied air, are therefore to be regarded in the light of good conductors crossing lines of magnetic force; we may therefore expect them to be the vehicle of electric currents. Such electric currents will of course react on the magnetism of the earth. Now, since the velocity of these upper currents has a daily variation, their influence as exhibited at any place upon the magnetism of the earth may be expected to have a daily variation also.

The question thus arises, Have we possibly here a cause which may account for the well-known daily magnetic variation? Are the peculiarities of this variation such as to correspond to those which might be expected to belong to such electric currents? I think it may be said that as far as we can judge there is a likeness of this kind between the peculiarities of these two things, but a more prolonged scrutiny will of course be essential before we can be absolutely certain that such currents are fitted to produce the daily variation of the earth's magnetism.

Besides the daily and yearly periodic changes in these upper convection currents we should also expect occasional and abrupt changes forming the counterparts of those disturbances in the lower strata with which we are familiar. And these may be expected in like manner to produce non-periodic occasional disturbances of the magnetism of the earth. Now it is well known that such disturbances do occur, and further that they are most frequent in those years when cyclones are most frequent, that is to say in years of maximum sunspots. In one word, it appears to be a tenable hypothesis to attribute at least the most prominent magnetic changes to atmospheric motions taking place in the upper regions of the atmosphere where each moving stratum of air becomes a conductor moving across lines of magnetic force; and it was Sir Wm. Thomson, I believe, who first suggested that the motion of conductors across the lines of the earth's magnetic force must be taken into account in any attempted explanation of terrestrial magnetism.

It thus seems possible that the excessive magnetic disturbances which take place in years of maximum sunspots may not be directly caused by any solar action, but may rather be due to the excessive meteorological disturbances which are likewise characteristic of such years. On the other hand, that magnetic and meteorological influence which Mr. Broun has found to be connected with the sun's rotation points to some unknown direct effect produced by our luminary, even if we imagine that the magnetic part of it is caused by the meteorological. Mr. Broun is of opinion that this effect of the sun does not depend upon the amount of spots on his surface.

In the next place, that influence of the sun in virtue of which we have most cyclones and greater meteorological disturbance in the years of maximum spots cannot, I think (as far as we know at present), be attributed to a change in the heating power of the sun. We have no doubt traces of a temperature effect which appears to depend upon the sun-period, but its amount is very small, whereas the variation in cyclonic disturbance is very great. We are thus tempted to associate this cyclone producing influence of the sun with something different from his light and heat. As far, therefore, as we can judge, our luminary would appear to produce three distinct effects upon our globe. In the first place, a magnetic and meteorological effect, depending somehow upon his rotation: secondly, a cyclonic effect depending somehow upon the disturbed state of his surface; and lastly, the well-known light and heat effect with which we all are familiar.

If we now turn to the sun we find that there are three distinct forms of motion which animate his surface particles. In the first place, each particle is carried round by the rotation of our luminary. Secondly, each particle is influenced by the gigantic meteorological disturbances of the surface, in virtue of which it may acquire a velocity ranging as high as 130 or 140 miles a second; and lastly, each particle, on account of its high temperature, is vibrating with extreme rapidity, and the energy of these vibrations communicated to us by means of the ethereal medium produces the well-known light and heat effect of the sun.

Now, is it philosophical to suppose that it is only the last of these three motions that influences our earth, while the other two produce absolutely no effect? On the contrary, we are, I think, compelled by considerations connected with the theory of energy, to attribute an influence, whether great or small, to the first two as well as to the last.

We are thus led to suppose that the sun must influence the earth in three ways, one depending on his rotation, another on his meteorological disturbance, and a third by means of the vibrations of his surface particles.

But we have already seen that, as a matter of fact, the sun does appear to influence the earth in three distinct ways—one magnetically and meteorologically, depending apparently on his period of rotation; a second cyclonically, depending apparently on the meteorological conditions of his surface; and a third, by means of his light and heat.

Is this merely a coincidence, or has it a meaning of its own? We cannot tell; but I may venture to think that in the pursuit of this problem we ought to be prepared at least to admit the possibility of a three-fold influence of the sun.

Even from this very meagre sketch of one of the most interesting and important of physical problems, it cannot fail to appear that while a good deal has already been done, its progress in the future will very greatly depend on the completeness of the method and continuity of the observations by which it is pursued. We have here a field which is of importance not merely to one, or even to two, but almost to every conceivable branch of research.

Why should we not erect in it a sort of science exchange into which the physicist, the chemist, and the geologist may each carry the fruits of his research, receiving back in return some suggestion, some principle, or some other scientific commodity that will aid him in his own field. But to establish such a mart must be a national undertaking, and already several nations have acknowledged their obligations in this respect.

Already the German Government have established a Sonnenwarte, the mere building and equipment of which is to cost a large sum. With an appreciation of what the spectroscope has done for this inquiry, the first directorship was offered to Kirchhoff, and on his declining it, Herr Vogel has been placed in charge. In France also a physical observatory is to be erected at Fontenay, on an equal, if not greater scale, of which Janssen has already accepted the directorship; while in Italy there are at least three observatories exclusively devoted to this branch of research. Nor must we forget that in this country the new observatory at Oxford has been so arranged that it can be employed in such inquiries. But what has England as a nation done?

Some years since, at the Norwich meeting of this Association, a movement was set on foot by Col. Strange which resulted in the appointment of a Royal Commission on the advancement of science, with the Duke of Devonshire as chairman. This Commission have quite recently reported on the steps that ought in their opinion to be taken for the advancement of scientific research.

One of their recommendations is expressed in the following words:—

"Important classes of phenomena relating to physical meteorology and to terrestrial and astronomical physics require observations of such a character that they cannot be advantageously carried on otherwise than under the direction of Government. Institutions for the study of such phenomena should be main-

tained by the Government; and in particular an observatory should be founded specially devoted to astronomical physics."

If the men of science of this country who procured the appointment of this commission, and who subsequently gave evidence before it, will now come forward to support its recommendations, it can hardly be doubted that these will be speedily carried into effect.

But other things besides observations are necessary, if we are to pursue with advantage this great physical problem.

One of these is the removal of the intolerable burden that has hitherto been laid upon private meteorologists and magneticians. Expected to furnish their tale of bricks, they have been left to find their own straw. Nothing more wretched can be imagined than the position of an amateur—that is to say, a man who pursues science for the love of it and is unconnected with any establishment—who has set himself to promote observational inquiries, whether in meteorology or magnetism.

He has first to obtain with great expenditure of time or money, or both, copies of the individual observations taken at some recognised institution. He has next to reduce these in the way that suits his inquiry; an operation again consuming time and demanding means. Let us suppose all this to be successfully accomplished, and a valuable result obtained. It is doubtless embodied in the Transactions of some society, but it excites little enthusiasm, for it consists of something which cannot be repeated by every one for himself like a new and interesting experiment. Yet the position of such men has recently been improved. Several observatories and other institutions now publish their individual observations; this is done by our Meteorological Office, while Dr. Bergsma, Dr. Neumayer, and Mr. Broun are recent examples of magneticians who have adopted this plan. The publication of the work of the latter is due to the enlightened patronage of the Rajah of Travancore, who has thus placed himself in front of the princes of India and given them an example which it is to be hoped they will follow. But this is only one step in the right direction; another must consist in subsidising private meteorologists and magneticians in order to enable them to obtain the aid of computers in reducing the observations with which they have been furnished. The man of science would thus be able to devote his knowledge, derived from long study, to the methods by which results and the laws regulating them are to be obtained; he could be the architect and builder of a scientific structure without being forced to waste his energies on the work of a hodman.

Another hindrance consists in our deficient knowledge as to what observations of value in magnetism and meteorology have already been made. We ought to have an exhaustive catalogue of all that has been done in this respect in our globe, and of the conditions under which the various observations will be accessible to outside inquirers. A catalogue of this kind has been framed by a committee of this Association, but it is confined to the dominions of England, and requires to be supplemented by a list of that which has been done abroad.

A third drawback is the insufficient nature of the present facilities for the invention and improvement of instruments, and for their verification.

We have, no doubt, advanced greatly in the construction of instruments, especially in those which are self-recording. The names of Brooke, Robinson, Welsh, Osler, and Beckley will occur to us all as improvers of our instruments of observation. Sir W. Thomson has likewise adapted his electrometer to the wants of meteorology. Dr. Roscoe has given us a self-recording actinometer, but a good instrument for observing the sun's heat is still a desideratum. It ought likewise to be borne in mind that the standard mercurial thermometer is by no means a perfect instrument.

In conclusion, it cannot be doubted that a great generalisation is looming in the distance—a mighty law we cannot yet tell what, that will reach us, we cannot yet say when. It will involve facts hitherto inexplicable, facts that are scarcely received as such because they appear opposed to our present knowledge of their causes. It is not possible perhaps to hasten the arrival of this generalisation beyond a certain point; but we ought not to forget that we *can* hasten it, and that it is our duty to do so. It depends much on ourselves, our resolution, our earnestness; on the scientific policy we adopt, as well as on the power we may have to devote ourselves to special investigations, whether such an advent shall be realised in our day and generation, or whether it shall be indefinitely postponed. If governments would understand the ultimate *material* advantages of every step forward in science, however inapplicable each may appear for the moment to the wants or pleasures of ordinary life, they would find reasons patent to the meanest capacities for bringing the wealth of mind, now lost on the drudgery of common labours, to bear on the search for those wondrous laws which govern every movement not only of the mighty masses of our system, but of every atom distributed throughout space.

## SECTION C.

### Opening Address of Dr.[1] Thomas Wright, F.R.S.E., F.G.S., President.

*On the Geological and Palæontological Character of the Country around Bristol.*

In taking this Chair to-day, I desire first to express my deep sense of gratitude to the Council of the British Association for the honour conferred on me, and secondly, to say how much I feel the responsibility of the position in which I am placed when I recollect the long list of distinguished *savans* who in former years have presided over this Section. The fact that Buckland, Conybeare, De la Beche, Forbes, Geikie, Hopkins, Jukes, Lyell, Murchison, Phillips, Ramsay, and other men illustrious in the annals of British Geology have filled this chair, may well make me doubt how far my own feeble powers are equal to an efficient discharge of its duties; however, I shall bring a willing mind and an honest determination to do my best on this occasion.

We have met again in one of the most interesting centres in England to all students of practical geology; for within a short distance of this spot we can examine some of the most instructive sections of Palæozoic and Mesozoic rocks, and study a magnificent collection of local fossils obtained from them. So I purpose occupying the short space of time allowed for this introductory address in attempting to give you a general outline of the geological character of the country around Bristol, with a *résumé* of some of its more remarkable Palæontological features, by way of inducing you to visit and study the admirable collection of local organic remains so well displayed in the Museum of the Bristol Philosophical Institution.

Geology is the history of the Earth; for it attempts to construct a table of phenomena, physical and chemical, organic and inorganic, which have succeeded each other from the past to the present, and on the terrestrial surface traces of its origin and progress are preserved.

That phase which we see to-day is only the most recent of its eventful history, and although the last, is not the final one, as the physical forces that are ever in action among its different parts are slowly and steadily producing new combinations, which in time will effect mutations in its structure, change its physiography, and remodel the whole.

There is probably no other place in England where, within so limited an area, typical examples of so many different formations occur as around this city; for within a short distance by road or rail we may investigate the Silurian, Devonian, Carboniferous, Triassic, Liassic, Oolitic, and Cretaceous formations, all of which will yield many interesting species for the cabinet of the palæontologist, and a valuable series of rocks and minerals for the student of Physical Geology.

These different formations in relation to the entire series of stratified rocks will be better understood by a reference to the Table on the following page, in which the periods, divisions, formations, and typical localities are given.

The localities in the Table may be grouped into six districts:—

| | |
|---|---|
| 1. Tortworth district. | 4. Bristol district. |
| 2. Mendip Hills. | 5. Dundry district. |
| 3. Radstock district. | 6. Bridgewater district. |

### 1. Tortworth District.

*Silurian.*—Tortworth has long been classical ground to the geologist, and was first brought into notice by Dr. Cooke, formerly (1799–1835) rector of the parish. This gentleman made an extensive collection of fossils from all the rocks in the district, which after his death passed through my hands, and I can therefore speak to the fact. A description of the Geology of Tortworth was made by Mr. Weaver,[1] and by Buckland and Conybeare.[2] These memoirs were written at a time when the

[1] Trans. Geol. Soc. vol. i. p. 317 (2nd series).
[2] Ibid. p. 210.

correlations of the then so-called Transition rocks were not understood; therefore they help us little toward a correct understanding of their age and character; it was not until Murchison had succeeded in making out the true relation and character of the upper fossiliferous beds beneath the Old Red Sandstone, and had arranged his groups by their organic remains in consecutive order under the name of the Silurian System, that the true age and relation of the Transition strata of Tortworth were understood. It then appeared that the Silurian rocks of Tortworth are the southern extension of the same formations which, extending through Micklewood Chase and the Vale of Berkeley, appear as a dome of Upper Silurian, rising near Tites Point on the left bank of the Severn near Purton Passage. The same rocks are found wrapping round the base of May Hill and Huntley Hill in the Forest of Dean, in the Valley of Woolhope, Herefordshire, on the western slopes of the Malvern Hills, and extending through Eastnor and Ledbury to Wenlock Edge, Salop. Whatever, therefore, is true relating to the Palæontological character of the Upper Silurians in these other localities, is equally correct of the same formations that lie in the miniature basin of Tortworth. The *Caradoc Sandstone*, or, as it is now called, the *Upper Llandovery Sandstone*, is the oldest rock at Tortworth, and forms the dominant stratum of the district. It covers an extensive area; and some small sections are seen at the south side of Micklewood Chase, and on both banks of the Avon near Damory Mill. Lithologically and palæontologically it is indistinguishable from hand specimens of the same formation at May Hill. It abounds in fossils: *Pentamerus*, *Strophomena*, *Orthis*, *Atrypa*, *Spirifera*, and *Leptæna*, with broken Trilobites belonging to the genera *Trinucleus*, *Calymene*, *Illænus*, and *Phacops*, are found, together with the stems of Crinoids and Tentaculites.

The *Wenlock Limestone* is exposed at Falfield Mill and Whitfield, and other places; from its various beds the characteristic Upper Silurian Corals are collected, as *Favosites*, *Syringopora*, *Halysites*, *Porites*, *Caryophyllia*, and *Acervularia*. Crinoidal stems are very abundant. Many Brachiopoda, as *Leptæna*, *Atrypa*, *Orthis orbicularis*, and Gasteropoda, as *Euomphalus discors* and *Euomphalus funatus*, are collected, with fragments of *Calymene Blumenbachii* and *Phacops caudatus*. The *Ludlow Rock* is best exposed at low-water mark on the west bank of the Severn at Purton Passage, where it rises in a dome-shaped mass, and dips away beneath the beds of Old Red Sandstone of the Devonian series on the opposite shore; the upper portion of this formation consists of greenish-grey micaceous beds, with *Leptæna lata*, *Orthis unguis*, and *Terebratula Wilsoni*, which probably represent the Aymestry limestone.

TABLE I.—Geological Formations in the Bristol Districts.

| Periods. | Divisions. | Formations. | Typical Localities. |
|---|---|---|---|
| POST TERTIARY | Recent | Alluvium | Bristol, Shirehampton. |
| | | Peat | Cheddar, Glastonbury. |
| | Post Pliocene | Gravel | Cheddar railway, Keynsham, Saltford. |
| TERTIARY | - - - | - - - | Absent. |
| CRETACEOUS | - - - | Greensand | Postlebury. |
| JURASSIC | Upper Oolite | Coral Rag | Absent. |
| | Middle Oolite | Oxford Clay | Cloford. |
| | Lower Oolite | Cornbrash | Cloford, Marston Bigot. |
| | | Forest Marble | Chickwell, Faulkland. |
| | | Bradford Clay | Bradford. |
| | | Bath Oolite | Coombedown Lansdown P. |
| | | Fuller's Earth | North Stoke, Lansdown, Box. |
| | | Inferior Oolite | Dundry, Cotteswold Hills. |
| LIASSIC | Upper Lias | Liassic Sands | Dundry, Midford, Frocester. |
| | | Upper Lias Clay | Dundry, Midford, Frocester. |
| | Middle Lias | Marlstone | Dundry, Sodbury, Stinchcombe. |
| | | Clays | Dundry, Sodbury, Stinchcombe. |
| | Lower Lias | Clays | Horfield, Pell. |
| | | Limestones | Keynsham, Saltford. |
| TRIASSIC | Upper Trias | *Avicula contorta* | Aust, Beechum, Garden Cliff. |
| | | Keuper | New River, Cotham. |
| | | Dolomitic Conglomerate | Bristol, Portishead, Clevedon. |
| PERMIAN | - - - | - - - | Absent. |
| CARBONIFEROUS | Upper | Coal Measures | Mangotsfield, Radstock, &c. |
| | | Millstone Grit | Brandon Hill, Fish-ponds, &c. |
| | | Upper Shales | Clifton, Ashton, Fish-ponds. |
| | Lower | Carboniferous Limestone | Clifton, Mendips, Tortworth. |
| | | Lower Shales | Clifton, Clevedon, Tortworth. |
| DEVONIAN | Old Red | Sandstones | Clifton, Portishead, Mendips, &c. |
| | | Conglomerates | Clifton, Portishead, Mendips, &c. |
| UPPER SILURIAN | - - - | Ludlow | Berkeley, Purton Passage. |
| | | Wenlock | Tortworth, Falfield. |
| | | Upper Llandovery | Tortworth, Damory. |
| IGNEOUS ROCKS | - - - | Greenstone | Damory, Charfield, Woodford. |
| | | Basalt | Uphill, Mendips, Weston. |

*Devonian.*—The Old Red Sandstone, in its upper parts, consists of fine-grained thin flagstones of a whitish-grey colour; and Tortworth Court is built of these fine building beds. This upper division is underlain by coarse quartzose conglomerates, and at the base by red sandstone, which rests on the Llandovery strata. The same succession of beds is very persistent, with conglomerate in the centre and lower third, and sandstone above and at the base.

*Carboniferous.*—The Bone Bed at the base of this formation is well developed, together with the Lower Limestone Shales. *Psammodus linearis*, *P. lævissimus*, Coprolites, and *Pileopsis angustus*, Phil., a shell of the Carboniferous Limestone, are the leading fossils here.

*Millstone Grit and Coal Measures.*—These beds have been fully and accurately described in the "Geological Transactions," by Weaver, Buckland, and Conybeare, accompanied by many valuable sections. They consist of Millstone Grit, Lower Coal Measures, Pennant Sandstone, and Upper Coal Measures; the whole series may be studied and examined in this district. A section constructed from Tortworth Green to Frampton Cotterell gives the following:—Tortworth Green, Old Red; the Court and Park, Lower Limestone Shales; Ley Hill and Cromhall. Carboniferous Limestone; Cromhall Heath, Millstone Grit; Sweethouse, Lower Coal Shales; Sweethouse to Robin's-wood House, Pennant, and from Robin's-wood House to Frampton Cotterell, Upper Coal Measures of the Coal-pit Heath basin.

An able paper on this subject, with Map and Sections, by my friend Mr. Etheridge,[1] F.R.S., will be found in the papers of the Cotteswold Club.

*Dolomitic Conglomerate.*—Weaver described this formation as composed principally of "rounded and angular fragments of limestone, exceeding the size of the head, with fragments also of quartz and hornstone. These are all cemented together by a calcareous paste, which is frequently of a marly nature—or of a carbonate of lime either of an earthy or compact structure;" the cement is generally magnesian, and in this there are many cavities frequently lined with crystals of calcareous spar and quartz, and also with the sulphate of strontian.

This remarkable formation forms a kind of irregular broken fringe, hanging on the flanks of the older rocks, and resting unconformably upon them. We shall meet with this conglomerate again in connection with the beds in the Mendip Hills, and in the Clifton section.

*New Red Sandstone.*—The upper and central members of the New Red Sandstone are found near Tortworth; they consist chiefly of red clay and marl.

*Avicula contorta* beds have been found by the Earl of Ducie in the form of the Bone Bed, the series resting on the inclined edges of the Carboniferous Limestone.

### 2. Mendip Hills.

The Mendip Hills proper extend from Bleadon Hill near Hutton on the west, to Elm and Whatley on the east; and they strike nearly due west and east, and are about thirty miles in length, with an average breadth of five to six miles. They constitute the southern base of the Bristol Coal Field, or the base of an almost equilateral triangle, formed by the Palæozoic rocks, comprising the area from Purton Passage and Tortworth to the south slopes of the Mendips; this includes the outlier Bream Down, which is only a westerly prolongation in the Severn, separated from the main range of the Mendips by the alluvial flat of the estuary of the Axe.

The Lithology of the Mendips consists of Old Red Sandstone, Carboniferous Limestone, and Trias, the latter represented chiefly by the Dolomitic Conglomerate, which lies unconformably on the Old Red and Carboniferous, flanking nearly the entire range of hills, and in places capping their summits.

Numerous islands of Carboniferous Limestone surrounded by Triassic rocks occur east of Wells and south of Croscombe, also encircled by fringes of Dolomitic Conglomerate, of which Church Hill, Worminster, and Knowl-foot Hill are examples; these outliers testify to the southern extension of the Carboniferous Limestone beneath the New Red Sandstone and Lias south of the Mendips, and lend us aid in determining the probable position of deep-seated Coal Measures similar to those at Vobster, Colford, Edford, Holcombe, &c., north of the Mendip range.

The lower flanks of the northern portion of the range are covered by the New Red Sandstone, that of the south being a mere strip traversed by the Wells and Axbridge Railway, the peat plains and bogs of Sedgmoor covering them up to a certain level to the east of the meridian of Glastonbury. The Lias occupies an extensive plain, masking likewise the older rocks beneath.

*Old Red Sandstone* forms the oldest stratified rock, and is, strictly speaking, the axis of the Mendip Hills. It is exposed in four well-marked areas along the highest ridge:—(1) Blackdown; (2) North Hill and Pen Hill; (3) Beacon Hill; and (4) Downhead Common, which is the largest exposed tract. The intervening areas are occupied by a mantle of Carboniferous Limestone, which arches over and covers the underlying Old Red, denudation having yet spared the limestone.

The Old Red is exposed along two anticlinal axes, these being, indeed, the chief cause of its exposure; the axes being post-Carboniferous and pre-Triassic, are not traceable beneath or where the patches of Dolomitic Conglomerate and cherty Lias cover up the Old Red Sandstone and Carboniferous Limestone, as at Harptree Hill, Rowham, Shipham, &c.

The most northerly anticlinal brings up the fine range of Blackdown, on the north, south, and east of which occur the Lower Limestone Shales resting on Old Red.

The northern dip of the anticlinal is higher than the southern, being in places as high as 54° in the north, whilst in the south it does not exceed 20°. This anticlinal is traceable from near the exposure of the igneous rock at Uphill, along Bleadon Hill, thence under the New Red Sandstone to Padingham, and Dolomitic Conglomerate and Calamine beds of Shipham, through the Old Red Sandstone of Blackdown, and on through the Carboniferous Limestone of Lamb-bottom, where it is lost under the cherty Rhætic beds of Harptree Hill. From Little Elm on the extreme east, to Masbury Castle nearly due west of the range, the Old Red is again exposed for three miles, which is likewise due to the anticlinal axis.

At Masbury Castle we lose trace of this S.E. anticlinal, and a second and parallel one to that of Blackdown occurs, ranging from the Old Red of North Hill through the Carboniferous Limestone of Stoke Warren, and last under the Dolomitic Conglomerate of North Draycott. This may join the great anticlinal near Egar Hill. We thus see that the strike of the Mendips was induced by a force which has brought out its oldest rock to the surface, and thereby produced the present physiography of the bold range of hills we are now considering.

*Carboniferous Limestone* surrounds the exposed and concealed nucleus of Old Red, and is conformable therewith both in dip and strike. The Carboniferous Limestone has grand development in the Mendips, and constitutes the great mass of the chain, having a continuous spread of five miles between Westbury Beacon and Abbey, also between Croscombe and Emberrow. The Lower Limestone Shales are nowhere more finely exposed than around and resting on the upper members of the Old Red Sandstone, and are highly fossiliferous throughout, the beds being crowded with *Strophomena*, *Chonetes*, *Spirifera*, Polyzoa, the ossicula of Crinoids, and many Trilobites, presenting a strong contrast to the barren beds of the Old Red on which they conformably rest. The Shales are well developed around Blackdown, especially to the east of Charterhouse, at Rowbarrow and Priddy, west of North Hill, and Nine Barrows; and east of Egar Hill they attain a thickness of 500 feet, and are extremely rich in organic remains. They present an extended outcrop from Masbury to Stoke Lane, and Leigh upon Mendip, and in the Downhead beds near Asham Woods. The local development of these argillaceous beds of the lowest division of the Carboniferous Limestone first gave origin to the name Lower Limestone Shales. They are almost special to the west of England, and are exposed on both flanks of the Mendip range. On them rest the thick-bedded strata of the Carboniferous Limestone, which is everywhere traceable for thirty miles from Oldford, the gorge of the Vallis to Elm on the east, to the distant headland of Bleadon in the west, and everywhere abounding more or less with organisms which form the leading fossils in its beds.

*Coal Measures.*—On the northern flank of the Mendips, between Binegar and Wells, and resting on the Millstone Grit, highly faulted and contorted, are the well-known Coals of Vobster, Holcombe, Pitcot, &c., that portion on the west at Stratton on the Fosse, Downside, &c. being covered by Dolomitic Conglomerate, the eastern side at Newbury and Vobster being overlain by the same rock and the Inferior Oolite. There is no reason why we should not conclude that the Coals of the northern side once extended across the Mendips and now lie deeply buried along the south parts of the range. At Ebber rocks, west of Wells, we have evidence of the Millstone Grit resting on the Carboniferous Limestone; and the elevation of the Mendips being post-carboniferous, lends an additional reason for the occurrence of the Coals of the northern area to the south of the Mendips, and beneath the Lias and Peat plain of Glastonbury, Castle Carey, the Pennards, and the Poldon Hills. No Coal area in the United Kingdom is so disturbed and folded both along its strike and on the dip of the Coals as those of North Mendips; and like the Coals of the "Mons Coal-field" in Belgium, which exists under similar conditions, the seams are vertical and thrown over, so that the same seams are passed through by shafts two or three times. The Vobster and Holcombe Coal-seams are the same as those at Ashton and Kingswood near Bristol, Twerton near Bath, and probably the same as those at Yate. They underlie the whole area between the Mendips and Bristol, and are probably the same that occur at Kingswood and underlie the Pennant at Coal-pit Heath.

*The Trias.*—Two divisions of this group are greatly developed around and upon the Mendips, especially the inferior or Dolomitic Conglomerate, a peculiar and local condition of the base of the Keuper Sandstone of the Bristol and South Wales Coalfields, chiefly that portion of the latter which extends from Cardiff to Bridgend. The entire range of the Mendips is surrounded by Dolomitic Conglomerate; and ten or twelve patches still remain as unconformable undenuded masses of that formation resting upon the older rocks forming the massive range of the Mendips. This remarkable deposit completely covered the

[1] Proceedings of the Cotteswold Naturalists' Field Club, p. 28, 1865.

range when at a lower level, its partial removal being conclusively shown by the remnants that still cling to the steep face of the northern and southern flanks of the Mendips.

This Conglomerate is composed entirely of greater or lesser fragments of the older rocks composing the hills, and is the result of the denuding action of the sea that deposited the Keuper beds. This marine denudation took place when the entire area occupied by the Mendips and Coal-basin underwent depression, the Dolomitic Conglomerate and sandstones accumulating *pro ratâ* with the depression and consequent destruction of the rocks offered for resistance. This conglomerate, the "*overlie*" of the coal-miners of the Bristol basin, although visible only upon the Palæozoic rocks surrounding the coal-bearing area, is nevertheless entirely spread over them, and beneath the New Red Sandstone that occupy nearly the entire area from Tortworth to the southern flanks of the Mendips, its presence being marked by the marls and sandstones of the Keuper, the Lias limestones, and in other places the Oolitic rocks that lie within the Coal-basin, especially along its south-east border from Bath to Wells. We have no physical evidence more convincing of denudation, elevation, and depression over large areas of the earth's surface than what we can witness so easily and study so advantageously in the Mendip Hills; for this conglomerate rock here defines the limits between Mesozoic and Palæozoic times: the highly inclined Old Red Sandstone forms the nucleus of the chain, the Carboniferous rocks resting upon it; and the Coal Measures in conformable succession to the latter were all indurated, metamorphosed, elevated, and thrown into folds long prior to the time when, under slow depression, destruction, and denudation, the Dolomitic Conglomerate was laid down by the Triassic sea—the resultant of wave forces along a coast-line which was then the Mendip range, its shingle and boulders being slowly cemented by a magnesio-calcareous paste derived from the wasting beds of the great limestone series. For further details regarding the natural history of the Dolomitic Conglomerate I must refer to a valuable memoir on this formation by Mr. Etheridge, F.R.S.[1]

*The Rhætic.*—Singular beds of cherty and sandy deposits of Rhætic age occur in several parts of the Mendips, in places brecciated, or as a conglomerate, and resting either upon the Dolomitic Conglomerate or Carboniferous Limestone.

The fossils are either cherty, or they have been removed, and their moulds are formed of chert, or cavities are left where organisms existed.

These beds are exposed at East Harptree, Egar Hill, Ashwick, and Shepton-Mallet. In the Vallis they repose immediately on the upturned edges of the Carboniferous Limestone, and even fill in the numerous veins, pockets, and faults in that formation, with fossil species common to the beds.

Nowhere can the geologist read more clearly the physical history of the groups of associated rocks composing the structure of the Eastern Mendips than at Wells, the Vallis, Watley, Elm, Nunny, and Holwell, where Old Red Sandstone, Carboniferous Limestone, Coal Measures, Dolomitic Conglomerate, Rhætic beds, Lias, and Oolites are all exposed in natural sequence to each other. There can be no doubt that the Rhætic sea surrounded and covered the Mendips; for its remains are found reposing on the Old Red Sandstone, Carboniferous Limestone. Coal Measures, and Dolomitic Conglomerate, and pass upwards into the Lias beds.

*The Lias.*—Fragmentary portions of this formation are found resting upon the summits of the Mendips, covering respectively Old Red Sandstone, Carboniferous Limestone, Dolomitic Conglomerate, and Rhætic beds, and in the Holcombe and Barrington districts resting upon the Coal Measures, proving the former extension of the Liassic sea over the Mendips; for upon some of their highest points, as near as Castle Comfort, the cherty beds, with their characteristic fossils, are found; also at Chewton Mendip, Emberrow, Ashwick, &c.; and on the south side of the hills it is found at a considerable height, as at Dowside, Chilcott, and West Herrington. During the Lias age the Mendips must either have been an archipelago, or they were totally submerged beneath the sea which deposited the Liassic plain to the north and south. The re-elevation of the Mendip range has occasioned the removal by aqueous denudation of most of the Lias beds deposited on their summit, whilst along the southern flanks of the hills, and in the valley, a considerable thickness of this formation still remains *in situ*.

*Igneous Rocks.*—Mr. Charles Moore[2] has shown that there is an exposure of basaltic rocks (dioritic) along the anticlinal of the Mendips, a little west of Downhead, extending visibly nearly as far as Beacon Hill, between two and three miles in length and a quarter of a mile in width.

This igneous mass appears in the form of a dyke, and is coincident with the anticlinal line along the axis of the Mendips, which is here traceable for seven miles, and is again continued from near Harptree to Shipham.

There is likewise at the south end of Uphill cutting (Bristol and Exeter Railway), at the western extremity of Bleadon Hill, an extensive patch of igneous rock, discovered when that line was made, and described by Mr. W. Sanders, F.R.S.; this exposure was also in the line of the anticlinal, and ended in the fault which there crosses the line. This rock, according to Mr. Rutley's analysis, is a Pitchstone Porphyry, whilst Mr. David Forbes considers it a Dolerite.

Whether this dyke was really eruptive or overflowed the Old Red Sandstone is still a question to be solved; and whether it is co-extensive with the range is unknown; but its age must be subsequent to the Coal Measures—the whole of the Palæozoic rocks being disturbed alike, and lying at one general angle of inclination, the overlying secondary strata not being influenced or at all affected by these Palæozoic changes. The Old Devonian rocks in contact with the dyke are not altered or metamorphosed, thus establishing the facts of age and condition.

### 3. The Radstock District.

Among the many interesting features of the neighbourhood in which we are assembled is the Bristol Coal-field, which still offers an inexhaustible subject for scientific inquiry; extending from Cromhall in the north to Frome in the south, and from Bath in the east to Nailsea in the west, comprising an area of 238 square miles.

From a very early date it attracted the attention of geologists, and was long ago the subject of a paper by Mr. Strachey, which was published in one of the local societies. Dr. Buckland[1] contributed an able memoir on this Coal-field, in which a great quantity of important information was placed on record, which has been of the greatest possible use down to the present time.

Subsequently this area has formed the subject of able papers contributed to the North of England and South Wales Institutes of Engineers, by Mr. J. C. Greenwell, F.G.S., and Mr. Handel Cossham, F.G.S., and to other scientific societies by Mr. Robert Etheridge, F.R.S., and Mr. Charles Moore, F.G.S.

During the past twelve years Mr. J. M'Murtrie, F.G.S., of Radstock, has been continuously engaged in working out the physical geology of the district, and has contributed a series of memoirs on the Bristol Coal-field to the Bath and Somersetshire Societies, which have thrown a new and important light on these marvellous disturbances which have distorted the strata.

That part of the Report of the Royal Coal Commission bearing upon the Bristol Coal-field, and prepared by Professor Prestwich, and papers by Mr. Horace Woodward and Mr. John Anstey, have summarised our previous knowledge, and added recent facts thereto; but with all that has been done much remains to be investigated before a full history of the Bristol Coal-field can be written.

Although more or less connected throughout, the Coal-fields adjoining Bristol consist of three well-defined areas, called the Gloucestershire, Radstock, and Nailsea basins, each of which has its own distinctive features. The Gloucestershire is separated from the Radstock basin by the great Kingswood anticlinal, which intersects in a ridge-like form the entire Coal-field from east to west; and the Nailsea basin has been almost, if not entirely, cut off from the principal coal district by the elevated limestones of Broadfield Down. Of these three areas Radstock basin is the most extensive, both geographically and sectionally, a great portion of its thickness being yet entirely undeveloped. One of the features which will be remarked by visitors coming from other parts of England is the number and character of the Secondary formations by which the Radstock basin is overlain. Here and there, it is true, Mesozoic rocks have been denuded; but by far the greater portion of the Coal-field is hidden beneath a covering of New Red Sandstone, Lias, and inferior Oolite, and many of the shafts have had to pass through all these formations before the coal-seams were reached.

A very slight change in the geological circumstances of the past would have left us in entire ignorance of the existence of a Coal-field so far south as Bristol; and this reflection induces the

[1] Quart. Journ. Geol. Soc. vol. xxvi. p. 174 (1870).
[2] Ibid. vol. xxiii. p. 452 (1867).

[1] Trans. Geol. Soc. Second Series, vol. i.

hope that in other parts of the country (at present believed to be without coal, or, if present, to lie at such a depth from the surface that it cannot be worked) it may yet be discovered at a moderate depth.

Another feature of the Radstock Coal Measures is their great thickness, which Mr. M'Murtrie estimates at 8,000 feet. From this we may infer that, however limited the area in Somersetshire of which we have at present positive knowledge, we are very far indeed from the edge of that infinitely more extensive area which the Coal Measures of the South of England originally occupied, and within which outlying basins may still be found.

It is abundantly evident that the Bristol Coal-field was originally connected with that of the Forest of Dean and South Wales, with which it has many characters in common, although it differs in other respects.

In all we find the same arrangement of the different strata, namely:—1st, an upper division of productive Coal Measures; 2nd, a central mass of Pennant Sandstone; and, 3rd, beneath, a lower division of productive Coal Measures resting upon, 4th, the Millstone Grit. Hitherto it has been found impossible to correlate the seams of coal; but they present many points of general correspondence in the districts referred to; and the information obtained leads to the conclusion that their greatest sectional development occurs between Radstock and Bristol, according to the following estimate of the thickness of the strata, number of seams, and thickness of coal-seams:—

TABLE II.—Strata and Coal-Seams.

| Division of Strata. | Sectional thickness. | Number of Coal-seams. | Thickness of Coal-seams. | |
|---|---|---|---|---|
| | | | Feet. | Inches. |
| Upper Coal Measures..... | 2,600 | 16 | 26 | 10 |
| Pennant Sandstone.......... | 2,750 | 4 | 5 | 10 |
| Lower Coal Measures..... | 2,800 | 26 | 66 | 6 |
| | 8,150 | 46 | 97 | 26 |

This great sectional thickness is attended, however, with serious disadvantages; for although, according to the Report of the Royal Coal Commission, the Bristol Coal-field was estimated to contain 6,104 millions of tons of coal, a large portion of it lies at an unworkable depth. Another physical feature of the district is the thinness of many of the seams from which coal is at present obtained.

In many of the collieries seams of from 10 to 12 inches in thickness are extensively worked, thus setting a good example of economy of one of our most precious natural productions to other parts of England, where veins of similar thickness are left behind as worthless.

Another feature of the Radstock Coal-basin is the extreme richness of its beds in the fossil flora of the Coal Measures. The Pennant Sandstone and Lower Measures yield few plants; but the Upper divisions contain much finer specimens than I have seen elsewhere, and the fossil flora of Radstock preserved in Mr. M'Murtrie's museum is alone worth a journey to study and admire. The fossil ferns are in great variety and beautifully preserved. The *Sigillariæ*, *Lepidodendra*, and other acrogenous stems tell of the arborescent ferns that floated their plume-like foliage on the islands of the Carboniferous period, and the industry and genius of the man who has collected and preserved them for our instruction and delight. The animal remains are here very scarce; two or three species of the genus *Limulus*, and one or two *Anthracosiæ*, are all that have been found; and I have the satisfaction of adding that I am authorised to say that by previous arrangement Mr. M'Murtrie will be happy to show his museum to any members of the Association to whom the same might be interesting. As there will be, I understand, memoirs on the Radstock Coal-field, I must refer to these papers for further details on this interesting district.

### 4. THE BRISTOL DISTRICT.

In a radius of eight miles from the Guildhall we find exposures more or less complete of the following Palæozoic and Mesozoic formations:—1. *The Old Red Sandstone*; 2. *the Carboniferous Limestone*; 3. *Millstone Grit*; 4. *Coal Measures*; 5. *Dolomitic Conglomerate and New Red Sandstone*; 6. *Rhætic*; 7. *Lias, Lower, Middle, Upper*; 8. *Upper Lias Sands*; 9. *Inferior Oolite*; 10. *Fuller's Earth*; 11. *Great Oolite*; 12. *Alluvium*, with igneous rocks of Palæozoic age. Several of these formations I have already noticed in speaking of the Mendip Hills; therefore I shall only now add such special remarks as are required to complete their sketch in the Bristol district.

The *Old Red Sandstone* forms, as we have seen, the axis of the Mendip Hills, and here occurs as a massive rock in different regions of the Bristol Coal-field, forming ranges of hills that have been sculptured by denudation out of its anticlinal folds. The beds in general are very unfossiliferous.

In the neighbourhood of Portishead, however, the remains of some large fishes have been found in a hard conglomerate, belonging to the genus *Holoptychius*—reminding us of the fishes of the Old Red Sandstone of Scotland, which were all encased in a bony armour, and possessed some of the most remarkable forms of the ichthyic type. *Pterichthys* or wing-fish, *Holoptychius* or wrinkle-scaled fish, *Cephalaspis* or buckler-shielded fish, are all forms of the Old Red, and the earliest representatives of the class Pisces in the Palæozoic rocks.

The Carboniferous Limestone is a great marine formation, and is formed of the sediments of an extensive and wide-spreading sea; the beautiful scenery so characteristic of the Avon, Severn, and Wye is in a great measure due to the development of this rock in these regions. One of the grandest sections of all the beds of the Carboniferous Limestone is that exposed in the gorge of the Avon near Clifton, where it is seen resting on the Old Red Sandstone, and overlain by the Millstone Grit.

The various conditions of the old sea-bottom in which this mass of calcareous rock was formed may here be studied with ease. The entire thickness of the strata exposed is upwards of 4,000 feet; of this the Old Red Devonian is 768 feet, the Carboniferous Limestone 2,338, and the Millstone Grit 950 feet. This magnificent section has repeatedly been the subject of memoirs by Buckland,[1] Conybeare,[2] Bright,[3] and Williams,[4] who have given ample details of all its different beds.

The Lower Limestone Shales, 500 feet in thickness, are very fossiliferous; they consist of alternations of shales and limestone, with a bone-bed near their base; in some places beds several feet thick are formed of the ossicula of Crinoids. In the main Limestone series you have a succession of Brachiopoda; *Spirifera*, *Producta*, and *Orthis* follow each other. Of Lamellibranchs we find *Aviculopecten*, *Cardiomorpha*, &c., with Gasteropods, as *Euomphalus* and *Bellerophon*, and Cephalopods, as *Goniatites*, *Orthoceras*, *Actinoceras*, &c. To these may be added the teeth and defensive spines of large shark-like and other fishes, as *Cladodus*, *Psammodus*, *Orodus*, *Holoptychius*, &c. Some of the coral strata in the upper part of the series are very interesting, and extremely rich in very beautiful specimens of Actinozoa, belonging to the reef-building groups of the ancient sea, as *Michelinia*, *Amplexus*, *Lithostrotion*, *Syringopora*, *Lonsdaleia*, &c., reminding us of the structure of coral reefs in our present seas. Associated with the coral masses are other organisms which lived on the reefs, or in shallow lagoons. The coral beds are covered by strata formed of Oolitic limestone and other detrital materials derived from the débris of wasted reefs, and formed along the shores of the ancient coral strand; sections of these oolitic beds prepared as slides for the microscope disclose the fact that the nucleus of the oolitic granules is often the shell of Foraminifera.

*Millstone Grit* is well seen at Brandon Hill; it rests upon the Limestone, and attains a thickness of 1,000 feet. On this repose the Coal Measures of the Bristol Coal-field, which I have already described in connection with the Mendip and Radstock districts.

*Dolomitic Conglomerate.*—The Palæozoic rocks of the Bristol Coal-field are here and there covered over by patches of Dolomitic Conglomerate lying unconformably on their upturned edges, at heights varying from 20 to 300 feet above the Avon. This remarkable formation is very well seen in the new road leading from the Hot-wells to Clifton and Durdham Down. It has been

[1] "On the South-Eastern Coal District of England," Geol. Trans. 2nd series, vol. i.

[2] Geol. Trans. 1st series, vol. iv.

[3] "On the Limestone Beds of the River Avon," Geol. Trans. 1st series, vol. v.

[4] "Memoirs of the Geol. Survey," Sir H. De la Beche's Essay, vol. i. p. 113.

long well known to geologists, and was in former days described by Bright, Gilby, Buckland, and others.

*Rhætic.*—Between the uppermost beds of the grey marls of the Keuper and the lowest beds of the Lias there lies a remarkable assemblage of strata, which I formerly described,[1] as the "*Avicula contorta* beds," from that shell forming the leading fossil therein. The name Rhætic has since been given to the series, from a supposition that the beds are identical with some that occur in the Rhætian Alps, which is, however, more than doubtful. Typical sections of the *Avicula contorta* series are exposed at Garden Cliff, Aust Cliff, Penarth, and Watchet on the Severn, and at Weston, Keynsham, Willsbridge, and Saltford near Bath, and Puriton, Uphill, and Wells in Somersetshire, as well as at many other localities. Two of the most classical of the series are Garden Cliff and Aust Cliff; the latter has been long known to continental geologists as the Bristol Bone-bed. In the upper part of the section are dark grey shales, intersected by bands of limestone; *Avicula contorta*, *Cardium*, *Rhæticum*, *Pecten Valoniensis*, *Axinus*, &c. are found in these. The Bone-bed consists of a hard dark-grey siliceous grit full of the bones, spines, scales, and teeth of fishes belonging to the genera *Nemacanthus*, *Acrodus*, *Sargodon*, *Hybodus*, *Ceratodus*, &c. Beneath this thin Bone-bed, with its ichthyic débris is a bed of shale which rests upon the grey marls of the Keuper. A similar succession of strata is repeated in most of the other typical sections. I have named especially those of Garden Cliff, Penarth, Uphill, and Watchet.

Aust has been long famous for its *Ceratodus* teeth, and is, I believe, the only locality where they are collected. You will find a fine series of them in the Bristol Museum. This wonderful collection is quite unique and will well repay an attentive examination.

The only living representative of the genus *Ceratodus* now lives in the rivers of Queensland; and a fine specimen was lately purchased for and presented to the Museum by W. W. Stoddart, Esq., F.G.S., for the purpose of showing the comparative size of the recent and fossil teeth.

### 5. Dundry District.

*The Oolitic Formations.*—The Oolitic formations will long remain classical ground to English geologists, as it was whilst studying these rocks in Wilts and Somerset that Dr. William Smith first acquired that knowledge which enabled him to "identify strata by organic remains," and establish a true natural system of stratigraphical geology.

The Oolitic period admits of a subdivision into three groups—the Lower, Middle, and Upper; each group is based on a great argillaceous formation, on which rest minor beds of sands and cream-coloured Oolitic and Pisolitic limestones. The argillaceous formations form broad valleys, extending diagonally across England in a direction north-east by south-west. The limestones constitute low ranges of hills, with escarpments facing the south-west, and overlooking the valleys. The Lower Oolites rest on the Lias, the Middle Oolites on the Oxford Clay, and the Portland and Upper Oolites on the Kimmeridg Clays.

The *Lias Formation* is well developed around Bristol; and many interesting and instructive sections of the Lower beds may be studied at Horfield, Keynsham, Saltford, and Weston, whilst the Middle and Upper divisions are exposed in other localities. It has been often repeated of late years that the geological record is imperfect, and that many of the leaves, and even whole chapters of the Rock-book on which the hieroglyphics of its history were written, are wanting; yet "Time, which antiquates antiquities, and hath an art to make dust of all things, hath yet spared these minor monuments;" for it is certainly true that the Jurassic formations contain a marvellously complete record of the succession of life in time during their deposition from the dawn of the Lias until the close of the Coral Sea, amid whose islands fossil *Cycadeæ* luxuriantly flourished, and whose remains are buried in their native Dirt-beds in the Portland Oolites.

I have shown elsewhere that the three divisions of the Great Lias formations admit of several subdivisions or zones of life, each characterised by a group of species which individualise it. A careful examination of these subdivisions has further proved that there is no confusion in the rocks when carefully examined—that Nature is always true to herself, although all geologists are not true to Nature. The fossils of the Lower Lias are quite distinct from those of the Middle Lias, and both specifically different from those of the Upper.

[1] Quart. Journ. Geol. Soc. vol. xvi. p. 374.

The *Ammonites* are important leading Liassic shells, that appear to have had a limited life in time, but a wide extension in space; and they have greatly aided us in determining periods and making out the history of the Liassic sea. The great Sauropterygia, represented by the *Plesiosaurus*, and the Ichthyopterygia by the *Ichthyosaurus*, are remarkable forms of Reptilia, adapted to the waters of that epoch, whilst the Dinosauria, represented by *Scelidosaurus*, the Pterosauria by the *Pterodactylus*, lived in this area during the Lias age; magnificent specimens of these different forms of reptiles adorn the walls of the Bristol Museum.

*The Jurassic Age.*—Dundry Hill, 700 feet in altitude, is the most westerly outlier of the Oolitic range, from which it is nine miles distant. It is a locality of great interest to the local naturalist, as it affords capital lessons of stratigraphical geology, admirable examples of surface-rock sculpture by denudation, and a commanding point of view for surveying the same, and showing the grand panorama in the midst of which it stands. The greater portion of the hill is composed of Lower Lias strata, which are well exposed at Bedminster Down, Whitchurch, Keynsham, Queen Charlton, Norton, Malreward, Winford, and Barrow. The beds consist of alternations of limestones and shales, having a total thickness of 550 feet. The Middle Lias and Marlstone are feebly developed, and the Upper Lias represented by some thin clays, with dwarfed specimens of *Ammonites bifrons* and *A. communis;* and the Upper Lias sands, from one to two feet thick, are not fossiliferous. On these rest beds of Inferior Oolite rock which have long yielded a very fine series of organic remains, some of the best of which are now preserved in the Museum collection. The Inferior Oolite of the south of England admits of a subdivision into three zones of life: the *Lower* resting upon the Lias sands has the *Ammonites Murchisonæ* as its leading fossil; the *Middle* contains a large assemblage of Mollusca, and especially of *Ammonites*, among which *Ammonites Humphriesianus*, *Sowerbyi*, *concavus*, and *Blagdeni* are conspicuously characteristic; the *Upper* contains *Ammonites Parkinsoni*, *Martinsii*, and *subradiatus*, with many Echinoderms and a large series of reef-building chorals. These three subdivisions are rarely all developed in the same section; but the order of their sequence in nature is as stated in Dundry. The lower beds are feebly represented; and there is an immense development of the middle and upper divisions.

In the iron shot shelly beds there is a fine assemblage of Lamellibranchs; and the stratum which covers them is very rich in Ammonites, many with their shells preserved, and having their oral lobes and other appendages *in situ*.

These are succeeded by other conchiferous strata; and the whole is covered by Ragstone and Building-stone, forming the upper zone, with *Ammonites Parkinsoni*, *Echinidæ*, and Corals. The stratigraphical, lithological, and palæontological conditions seen in the Oolitic capping of Dundry Hill, are repeated in other localities in Gloucestershire, Somersetshire, and Dorsetshire; and a full development of all the zones in actual superposition may be examined in certain sections in the Cotteswold Hills, as at Leckhampton and Cleeve.

The Fuller's earth must be studied at North Stoke and Lansdown, and the Great Oolite at Coombedown, Lansdown, and other localities around Bath; the typical Bradford Clay, with Apiocrinital heads and stems, and beautiful Brachiopoda near Bradford; the Forest Marble and Cornbrash at Faulkland, Chickwell, Marston Bagot, and Cloford. The Middle Jurassic rocks are admirably exposed near Calne, and the Upper Jurassic near Swindon, Wilts.

The great importance of the Bristol district as a source of mineral wealth, added to the complicated structure of this region, led my old friend Mr. William Sanders, F.R.S., to construct an elaborate geological map of the Gloucestershire and Somersetshire Coal-fields and adjacent country, on the scale of four inches to a mile. The topographical portion of this undertaking was reduced to one scale from the Tithe-Commission Maps; and Mr. Sanders traced out all the geological boundary lines in the field, and laid them down in MS. copies of the Tithe Maps, making copious notes of the strata as he proceeded with his work. The whole was finally reduced to one scale four times the size of the Ordnance-Survey Maps, and reproduced with the most scrupulous care by Mr. Stratton, who for many years assisted Mr. Sanders with the work which he had made the chief object and occupation of his later life; and it is but simple

justice to say that, single-handed, no such exact map for any one area was ever before constructed, either as regards scale or details. This undertaking occupied its author 15 years, fills 19 separate folio maps, and is a most valuable acquisition to the estate-agent, mineral engineer, and practical geologist. Its real merits can only be fully appreciated by those who understand how much patient labour, long-sustained energy, and high mental qualities were required to complete so extended a survey over such a complicated piece of country. In doing this, however, Mr. Sanders has made his scientific reputation, enriched his native country, and achieved a success which falls to the lot of few men. Having considered the stratigraphical relation of the rocks in the Bristol district, I desire now to say a few words on a branch of the subject which falls more immediately within the range of my own special studies—I mean the organic remains found imbedded in these strata. The science of Palæontology (*palaios*, old; *onta*, beings) forms an immense field of observation, and one that widens more and more every year. It is impossible to enter upon any of its details now; but some of its principles may be satisfactorily explained, and this I shall endeavour to do.

It is now established, 1st, that the stratified rocks containing organic remains admit of a division into four great groups, representing four great periods of time:—*a*, the Palæozoic or Ancient; *b*, the Mesozoic or Middle; *c*, the Cainozoic or Tertiary; and *d*, the Quaternary or Modern periods. 2nd. That each period is distinguished by its own hieroglyphic characters, which are graven on the rocks in definite and determinable characters. 3rd. That these hieroglyphics are the fossil remains or imprints of animals that lived in the water in which the sediments were formed in successive layers on the earth's crust, and are only found in the rocks they distinguish, so that it is possible to determine the age and position of the strata from which they have been collected, or, in other words, *identify strata by organic remains*; and by this key we are enabled to read the pages of the Rock-book, study the history of extinct forms of life, and determine their distribution in time and space.

Let us apply these principles to the subject we have in hand. The Palæozoic period comprises the history of the Cambro-Silurian, Devonian, Carboniferous, and Permian ages; and if we attentively examine the fossils of this period, contained in the cases of the magnificent Geological Museum of this institution, we shall see that all the organisms belonging to one age are entirely distinct from those belonging to the others. You will find, for example, in the case of the Silurian age, some beautiful corals, crinoids, and cephalopods, with a remarkable assemblage of Crustacea, the representatives of an extinct family, the Trilobitidæ, which are so highly characteristic of this age that the rocks may be called Trilobitic.

The Devonian age succeeds the Silurian; and among the corals and shells so well seen in this collection, we observe a striking resemblance to those of the Silurian on the one side and the Carboniferous Limestone on the other; but when closely examined we find that many are generically, and all are specifically distinct from both; besides this we discover that a new group of organisms of a different and higher type of structure are now introduced for the first time, namely, those remarkable forms of the ichthyic class the fishes of the Old Red Sandstone, and whose singular forms with their bony armour and osseous scales remind us of the remarkable fishes *Lepidosteus* and *Polypterus*, from North American, African, and Australian rivers of our time. The hieroglyphics, therefore, engraven on the strata of the second age are visibly different from those on the first.

The Carboniferous succeeds the Devonian; and here we find a marvellous development of the life of this age preserved in the cases of this institution. Pray study attentively the fine specimens of Anthozoa here exhibited, all derived from the upper beds of the Carboniferous Limestone at the gorge of the Avon, and showing very clearly that this portion of the section was formed in a tropical sea, and that the limestone is the product of the living energies of those Polyps, sections of whose skeletons lie there before you. Of the family FAVOSITIDÆ we see *Favosites, Alveolites, Syringopora Michelinia*; and of the family CYATHOPHYLLIDÆ we have *Cyathophyllum, Lithostrotion, Lonsdalia*, &c. Many of the beds of limestone are almost entirely composed of the ossicula of Crinoids; and we see the stems, arms, and calyces of these sea-lilies strewed in abundance in the rocks, such as *Actinocrinus, Poteriocrinus, Platycrinus, Cyathocrinus, Pentremites*, &c., with the remarkable ancient Sea-urchin *Palæchinus* associated with them. The Mollusca were chiefly represented by the Brachiopoda, which were very common in the Carboniferous age, as you may see in the large slabs containing *Orthis, Spirifera*, and *Productus* in great profusion. The Lamellibranchiata were represented by *Cardiomorpha* and *Conocardium*, and the Gasteropoda by *Euomphalus, Pleurotomaria*, and *Natica*, and the Cephalopoda by *Goniatites, Orthoceras*, &c. The Trilobites which formed so remarkable a feature in the fauna of the Silurian sea are here represented by a few specimens of *Phillipsia*, a dwarfed genus of this family. The fine collection of teeth and spines of large fishes from the Carboniferous Limestone enables us to compare the forms of this age with those of the Devonian already described, and shows at a glance that the ichthyic types in the seas of these two periods were entirely distinct, and both evidently adapted to conditions of existence widely different.

The life of the Carboniferous Limestone proves that it was a great marine formation accumulated during a long lapse of time out of the exuviæ and sediments of many generations of Mollusca, Echinodermata, and Actinozoa, the reef-building corals having contributed largely to the thickness of the Coral beds, and the wasted reefs of former generations having been used up again and again in the formation of the Oolitic beds which succeeded the reef-building periods.

The Coal Measures present a remarkable contrast to the Coral sea of the Carboniferous era. The Ferns (*Sigillaria, Lepidodendra*) and other arborescent Acrogens of the Coal-seams grew and flourished in low islands; and their remains were accumulated under conditions very different from those in which the thick-bedded limestones of the Avon section were formed. Good typical examples of the vegetation of this remarkable time in the world's history are well preserved in the large collection, filling several cases; these specimens are all very fine, and require, and I am sure will have, a careful examination.

With the close of Palæozoic time there appears to have been a great break in stratigraphical sequence of the fossiliferous rocks; mighty changes then took place. Volcanic agency was intense and active, flexing, contorting, and upheaving the older beds. These displacements in our area were post-carboniferous and pre-triassic, and are well exemplified in the unconformable position of the Dolomitic Conglomerate and New Red Sandstone of the Bristol district.

The Dolomitic Conglomerate contains the bones of Dinosaurian reptiles discovered in Durdham Down, and preserved in this Museum; they were described by Dr. Riley and Mr. Stuchbury in 1836,[1] and were then the oldest Dinosauria in Britain. Since that date the Triassic sandstones of Cheshire, Scotland, and North America have been found to contain the foot-imprints of *Cheirotheria*, and the same formation near Warwick the bones and teeth of remarkable reptiles belonging to the family *Labyrinthodontia*; subsequently it has been discovered that the coal-field of Münster-Appel in Rhenish Bavaria, and that of Saarbrück between Strasburg and Trèves, contain the skulls and bones of several species of air-breathing reptiles which were described by Goldfuss under the generic name *Archegosaurus*. The reptilian remains of the conglomerate, though now not the oldest of their class, still retain their interest for the Palæontologist, as they prove that highly organised Dinosauria lived on Triassic land. I must refer you to the original memoir for a full account of these bones, which enabled its authors to establish two genera for them. The one, *Thecodontosaurus*, has the teeth placed closely together in the jaw-bones. They are sharp, conical, compressed, and have their anterior and posterior borders finely denticulated, and the extremity slightly bent, like the teeth of *Megalosaurus*. *Palæosaurus* has the teeth compressed and pointed likewise; but one of the borders only is denticulated, and the other trenchant. The species are distinguished by the size and form of the teeth. The vertebræ resemble those of *Teleosaurus* in being contracted in the middle, and having their articular surfaces slightly biconcave; and the rest of the bones of the skeleton resemble the forms of the Lacertian type.

We know very little of the life of the Trias in the district under consideration, beyond the reptilian remains first noticed here, until we come to the close of this age, when we find upper grey marls of the Keuper overlain by and passing into a series of black shales and limestones known as the *Avicula contorta* or Rhætic beds, which have a great interest for us, as they comprise the famous Bone-bed of Aust Cliff known to all geologists. The leading fossils are *Avicula contorta, Cardium Rhæticum, Monotis decussata, Pecten Valoniensis*, and the small crustacean, *Estheria minuta*. The fishes are *Nemacanthus, Saurichthys, Hybodus*,

[1] Trans. Geol. Soc. 2nd series, vol. v. p. 349 (1840).

*Gyrolepis*, *Sargodon*, and *Ceratodus*, with bones of *Plesiosaurus* and *Ichthyosaurus*. It is the teeth of *Ceratodus*, or horned teeth, that have made Aust Cliff famous; and more than 400 different forms have been described. Mr. C. T. Higgins made the finest collection of these remains, which has been purchased for the Museum, and forms one of its rarest treasures. When these horned teeth, so called from the prominences they exhibit, were first described by Agassiz, the living species of this genus was not known; it is now ascertained that it lives in the Mary, Dawson, and other rivers of Queensland, and is called by the natives "Barramanda." The *Ceratodus* is very nearly allied to the *Lepidosiren*, is cartilaginous, a vegetable-eater, and, like the *Lepidosiren*, lives in muddy creeks; during the hot season it buries itself in the mud, whence it is dug up by the natives, its retreat being discovered by the air-hole through which it breathes; its nostrils are placed in the inside of the roof of the mouth.

A very interesting paper on *Ceratodus Fosteri* (the specimen in the Museum) by Mr. Stoddart, F.G.S., will be found in the "Proceedings of the Bristol Naturalists' Society," vol. i. p. 145.

The Lias, which succeeds the *Avicula contorta* beds, presents a remarkable contrast to them, and shows how much the life-conditions of every age depend on the physical agents that surround it. Two groups of animals appeared in great force in the Liassic sea—Ammonites and Reptiles.

The Ammonites of the Lower Lias beds, *A. angulatus*, *A. Bucklandi*, *A. Conybeari*, and others, attained a large size; and the middle and upper divisions of the same formations were all characterised by different species that marked horizons of life in these divisions. Associated with the Ammonites a large assemblage of other Mollusca are found, as *Gryphæa*, *Lima*, *Unicardium*, *Pholadomya*, *Cardinia*, *Hippopodium*, *Pleurotomaria*, and a profusion of Belemnites and large *Nautili*.

The Reptiles were very large, as you can see by the fine specimens on the walls: *Ichthyosaurus* and *Plesiosaurus* were the dominant forms of this class; and Pterodactyles with expanded wings performed the part of birds on the dry land of that era; so that the air, the estuary, and the ocean had each separate forms of Reptile life in the Lias age. Another change of conditions introduces us to new forms in the Lower Jurassic sea. A large number of species of Conchifera and Gasteropoda crowd the shelly beds of the Inferior Oolite; and new forms of Ammonites appertaining to groups entirely different from those of the Lias are found in abundance in Dundry Hill. In addition to the Mollusca we find many beautiful forms of Echinodermata, and a large collection of reef-building corals in the upper beds of the hill. Nothing gives us a clearer insight into the fact that all fossil species had a limited life in time than the distribution of the Echinodermata of the Jurassic strata, inasmuch as these animals possess a skeleton of remarkable structure, on which generic and specific characters are well preserved; they form, therefore, an important class of the Invertebrata for the study of the life-history of species in time and space; and this Table of the stratigraphical distribution of the Jurassic Echinoderms which I now exhibit reduces these observations to a practical demonstration.

The Oolitic rocks were formed in a coral sea analogous to that which rolls its waters in the Pacific between 30° on each side of the equator. In the Lower Oolites are four or five Coral formations superimposed one above another, with intermediate beds of Mollusca. The Middle Oolite is remarkable for the number and extent of its coral reefs, and the Upper Oolite for those found in the Portlandian series.

The Jurassic rocks were accumulated as sediments or shore-deposits under many changes of condition; and the idea of a slowly subsiding bed of the coralline sea gives us, perhaps, the nearest approach to what appears to have prevailed.

The Jurassic waters were studded with coral reefs, extending over an area equal to that of Europe, as they stretch through England diagonally from Yorkshire to Dorsetshire, through France from the coast of Normandy to the shores of the Mediterranean, forming besides a chain winding obliquely through the Ardennes in the north to Charente-Inférieure in the south, including Savoy, the Hautes-Alpes and Basses-Alpes, the Jura Franche-comté, the Jura chain of Switzerland throughout its entire length from Schaffhausen on the Rhine to Cobourg in Saxony, and along the range of the Swabian Alps and Franconian Jura. Throughout all this widely extended Oolitic region, coralline strata were accumulating through countless ages by the living energies of Jurassic Polypifera, as all the Madreporic limestone beds in these formations are due to the life-energies of different species of Anthozoa; and were we to venture to estimate the lapse of time occupied in the sedimentation of the coralligenous Oolites by what we know of the life-history of some living species, we should find good reasons for concluding that the Jurassic age must have been one of long duration. It is not the mere coralline structure *per se* that is due to Polyp-life, but the entire mass of Oolitic limestones are the products of the same vital force; for there could be no doubt in the mind of any competent observer who carefully examined such a rock as that in my hand that it was a mass of coral secreted by a Jurassic polyp, and that the Oolitic limestone which surrounds the coral stem is the product of a portion of a wasted reef which had been broken up, ground into mud, and constituted the calcareous paste that had coated particles on the shore, and formed by the roll of the waves the oolitic globules which were afterwards cemented by calcareous waters, and the whole transformed into the rock we call Oolitic limestone; and thus the genesis of the Oolites was due to the vital energies of the myriads of polyps that lived in the Jurassic seas.

The reefs that remain are merely fragments of what had existed; and those that have disappeared furnished the calcareous material out of which the Oolites of subsequent formations have been built up.

I have to thank my old friend Mr. Etheridge for the valuable notes he has supplied on the Mendip Hills (which he knows so well), and to Mr. M'Murtrie for his excellent notes on the Radstock district (which he has so long explored), and to Mr. Stoddart for kindness and assistance in many ways. Without their friendly co-operation it would have been impossible for me to have given so much exact information on the structure of the interesting and complicated region in which we have again assembled.

In these remarks I have carefully avoided any allusion to the origin of species, because Geology suggests no theory of natural causes, and Palæontology affords no support to the hypothesis which seeks by a system of evolution to derive all the varied forms of organic life from pre-existing organisms of a lower type. As far as I have been able to read the records of the rocks, I confess I have failed to discover any lineal series among the vast assemblage of extinct species which might form a basis and lend reliable biological support to such a theory. Instead of a gradation upwards in certain groups and classes of fossil animals, we find, on the contrary, that their first representatives are not the lowest, but often highly organised types of the class to which they belong. This is well illustrated in the Corals, Crinoids, Asteriadæ, Mollusca, and Crustacea of the Silurian age, and which make up the beginnings of life in the Palæozoic period. The fishes of the Old Red Sandstone we have already seen occupy a respectable position among the Pisces; and the Reptiles of the Trias are not the lowest forms of their class, but highly organised Dinosauria. *Ichthyosaurus*, *Plesiosaurus*, *Pterodactylus*, *Teleosaurus*, and *Megalosaurus* stand out in bold relief from the Mesozoic strata as remarkable types of animal life that were specially organised and marvellously adapted to fulfil important conditions of existence in the Reptilian age; they afford, I submit, conclusive evidence of special work of the Great Designing Mind which pervades all creation, organic and inorganic. In a word, Palæontology brings us face to face with the Creator, and shows us plainly how in all that marvellous past there always has existed the most complete and perfect relation between external nature and the structure and duration of the organic forms which gave life and activity to each succeeding age.

Palæontology likewise discloses to our feeble understanding some of those methods by which the Infinite works through natural forces to accomplish and maintain His creative design, and thereby teaches us that there has been a glorious scheme, and a gradual accomplishment of purpose through unmeasured periods of time; but Palæontology affords no solution of the problem of creation, whether of kinds, of matter, or of species of life, beyond this, that although countless ages have rolled away since the denizens of the Silurian beach lived and moved and had their being, the same biological laws that governed their life, assigned them their position in the world's story, and limited their duration in time and space, are identical with those which are expressed in the morphology and distribution of the countless organisms which live on the earth's surface at the present time; and this fact realises in a material form the truth and force of those assuring words, that the Great Author of all things, in these His works, is the same yesterday, to-day, and for ever.

## THE FRENCH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THIS year's session of this Association was opened last Thursday at Nantes, under the presidency of M. d'Eichthal, who is largely connected with French railways. The income of the Association for 1874 was 37,126 francs, and its capital fund amounts to 174,731 francs. In 1874, 5,350 francs were distributed for purposes of research, and already, owing to the generosity of three of the foundation members, 7,000 francs have been allotted to other purposes without trenching on the regular resources of the Association. This year 13 foundation members and 500 annual members have been added to the Association.

The President in his opening address spoke of the intimate connection between pure science and the various methods employed to satisfy the wants of humanity. It would be almost impossible, he said, to enumerate all the branches of human activity which owe their success to the researches of pure science,—Hygiene, Medicine, Surgery, the Fine Arts, Mechanics, Industry in all its branches, Mining, Metallurgy, Textile Industries, Lighting, Warming, Ventilation, Water Supply, &c. He then referred in detail to several examples of the influence which the results of science have had upon progress in the arts, with the motive forces of water, air and steam, mentioning a multitude of names of men eminent in pure science, from Pascal and Boyle down to Faraday and Sir William Thomson, upon the results of whose researches the great advances which have been made in machinery of all kinds have depended. M. d'Eichthal then spoke of electricity in connection with the names of Oerstedt, Ampère, Faraday, Becquerel and Ruhmkorff; passing on to speak at some length of the steam-engine in its various forms, of the progress which by means of scientific research is being made in its construction and its uses, and of the great services which this powerful application of a scientific discovery renders to man. M. d'Eichthal advocated the establishment of local centres of culture as the best counterpoise to that over-centralisation to which France owes so many of its social misfortunes. "In our time," he said, "science, history, literature, have great wants. Libraries, lecture-halls, laboratories, costly materials, instruments numerous and expensive, are indispensable to pupils for learning and to teachers for carrying on their researches; it is by putting, on a large scale, these resources at their disposal, that we can attract and fix in our midst men eminent in all branches of human knowledge."

M. Ollier, the General Secretary of the Association, gave a detailed *résumé* of the work done at Lille last year.

M. d'Eichthal has been very well received in Nantes, having been greeted with a serenade on Wednesday night.

The most notable foreigner present at the meeting, Admiral Ommaney, was elected, *pro honore*, president of the Geographical Section. The Geographical Congress of Paris has evidently diminished the attendance at the Nantes meeting, although M. Dumas and M. Wurtz have displayed on its behalf a most creditable zeal. Two ladies delivered addresses, on "Female Condition," and the "Sanitary Condition of Schools;" rather a novelty in France, ladies very rarely appearing as lecturers.

The excursions, which are by far the most interesting part of the proceedings, began on Saturday. A balloon ascent is contemplated for to-day. The balloon will be exceptionally large, 4,000 metres, conducted by local aëronauts who have organised an aërial sporting club.

## NOTES

AMONGST the objects which have been recently added to the galleries of the Paris Industrial Exhibition of Geography, and are attracting public notice, we may mention a collection of French birds exhibited by M. Bouvier, the collection of apes from the Gaboon, by the Marquis de Compiègne, and a number of antediluvian fossils from the Mentone Caves. The skeletons of two children which had been buried together are in a splendid state of preservation, exhibiting admirably the characteristics of prehistoric cave-life. These two young people were buried in the home of their parents, very probably because it was the only means of defending their bones against the teeth of ferocious hyænas and other large carnivorous animals which were disputing with man the empire of the future Gaul. The bones were covered with small shells, of which the loin cloth of the departed youngsters had been made. Neither of them had any ornaments in bone, jasper, or pearl, such as is generally discovered under similar circumstances when the skeleton is that of an adult. No child is buried with such objects in Polynesian islands, as none are allowed to wear them even when belonging to the regal families.

IN connection with the Exhibition and Congress, it is believed that a series of proposals will be made to the French National Assembly for the promotion of the study of geography. The principal and most effective is to have a relief map of each parish in the parish school, so that pupils may learn to understand the purpose of geographical maps.

THE large reflecting telescope at the Paris Observatory is completed, although it will not be brought into use for two or three months. The equilibrium of the tube is perfect, and it can be directed with the utmost facility on any part of the heavens, although it weighs about six tons.

THE Commission appointed by the Prefect of the Seine for deciding on the improvements to be introduced in the construction of lightning conductors have just published their report. They are of opinion that the conductors should terminate in a point of copper instead of platinum as recommended by the Academy, and propose to institute an annual inspection of lightning conductors, as recommended by M. Wilfrid de Fonvielle in his pamphlet, "Lightning Conductors and the necessity of controlling them." A series of measurements will be presented to the Municipal Council in the next session. The inspection is to take place in autumn, when the stormy season is over.

THE annual provincial meeting of the Iron and Steel Institute will commence, in Manchester, on Tuesday, September 7, under the presidency of Mr. William Menelaus. The Council of Owens College have granted the use of that building for the business meetings. On Tuesday, the Mayors of Manchester and Salford respectively will welcome the members of the Institute, and the remainder of that and Wednesday morning will be devoted to the reading and discussion of papers. On the afternoons of Tuesday and Wednesday, various works in the neighbourhood of Manchester will be open for inspection. On Tuesday evening there will be a conversazione in the Town Hall; on Wednesday evening the members will dine together in the Hulme Town Hall; and on Thursday they will visit works within easy reach of Manchester. On Friday, the whole day will be devoted to North Staffordshire.

DURING last week the British Archæological Association made frequent excursions to places around Evesham, and in the evenings a number of papers were read, mostly of strictly antiquarian interest. The Cambrian Archæological Association also held its annual meeting last week at Carmarthen, both meetings being brought to a close on Saturday. Next year the latter body meets at Abergavenny under the presidency of Mr. Freeman.

MR. HENRY WILLETT, writing with reference to the Sub-Wealden Exploration, states that the committee have "succeeded beyond their fondest anticipations in solving the original problem, and can now state with certainty that palæozoic rocks do not exist at a depth variously estimated at from 700 ft. to 1,700 ft." From 1,670 ft. to 1,750 ft.—the depth now reached—the strata are shattered and very soft, greatly retarding the work, and seriously imperilling any prospect of attaining a much greater depth. Although at any moment a change of strata may be reached, Mr. Willett is not sanguine that he ever will be able to

report more than that Kimmeridge clay has been discovered in Sussex, and that this clay is very thick.

An interesting geological discovery has been recently made during excavations for a new tidal basin at the Surrey Commercial Docks. On penetrating some 6ft. below the surface, the workmen everywhere came across a subterranean forest bed, consisting of peat with trunks of trees, for the most part still standing erect. All are of the species still inhabiting Britain; the oak, alder, and willow are apparently most abundant. The trees are not mineralised, but retain their vegetable character, except that they are thoroughly saturated with water. In the peat are found large bones, which have been determined as those of the great fossil ox (*Bos primigenius*). Fresh-water shells are also found. No doubt is entertained that the bed thus exposed is a continuation of the old buried forest, of wide extent, which has on several recent occasions been brought to the daylight on both sides of the Thames, notably at Walthamstow in the year 1869, in excavating for the East London Waterworks; at Plumstead in 1862-3, in making the southern outfall sewer; and a few weeks since at Westminster, on the site of the new Aquarium and Winter Garden. In each instance the forest-bed is found buried beneath the marsh clay, showing that the land has sunk below the tidal level since the forest flourished.

We have received a "Catalogue of the publication of the U.S. Geological Survey of the Territories, F. V. Hayden, Geologist in Charge." The catalogue covers twenty pages, and although the publication extends only from 1867, they already form quite a large library of reports, monographs, catalogues, &c., relating to all branches of the geology, natural history, meteorology, and other points of the extensive region which is being surveyed. The publications of the survey, we believe, Dr. Hayden is willing to send to any societies, libraries, or persons engaged in active scientific investigation who may desire them; those who do should communicate with Dr. Hayden, U.S. Geologist, Washington, D. C. (U.S.) Dr. Hayden is desirous of securing by exchange the publications of foreign countries in geology, palæontology, and natural history generally, to aid in the formation of a library of reference for the use of the Survey, and he hopes that all persons or societies who receive the publications of the Survey will aid him in this matter.

Vol. iv. of the second series of the *Mémoires* of the Royal Society of Science of Liége, contains only three papers, one of them a mere note of two pages on a new species of Lepidotus, *L. mohimonti*, by Dr. T. C. Winkler. The other papers are long treatises, one by Dr. E. Candèze, being a "Revision of the Monograph of the Elateridæ" (218 pp.), and the other a treatise "On the Calculus of Probabilities," by the late A. Meyer, published from the MSS. of the author by F. Folie (446 pp.)

Mr. J. Wood-Mason, of the India Museum, Calcutta, has lately directed attention to the presence of a chain of superorbital bones in the wood partridges (*Arboricolæ*), similar to that recorded by Mr. W. K. Parker in the tinamous.

The fourth number of the *Bulletin de la Société Impériale de Naturalistes de Moscou* contains papers on entomology, botany, geology, &c., by M. V. Motschoulsky, M.A. Petrovsky, M. H. Trautschold, and others, in the French and German Languages.

The Cincinnati Society of Natural History has lately received a bequest of $50,000 from Mr. Charles Bodman, of that city. The gift is absolute and without conditions.

A large meteor was observed at Niort (Deux-Sevres), on August 19, at 8.20 P.M. Although the moon was quite full, it was a magnificent spectacle. It made its appearance in the zenith, lasted thirty seconds, and disappeared in the south-east at an altitude of sixty degrees above the horizon. It must have been seen from other parts of France, but no record has come under our notice.

A chair of Organic Chemistry has been created in the Faculty of Sciences of Paris.

The additions to the Zoological Gardens during the past week include two Kinkajous (*Cercoleptes caudivolvulus*) from British Honduras, presented by Mr. James Wickin; a Central American Agonti (*Dasyprocta punctata*), two Brown Gannets (*Sula fusca*) from Costa Rica, presented by Mr. J. C. Hussey; a Woodford's Owl (*Syrnium woodfordi*) from Natal, presented by Mr. W. E. Oates; a Purple-capped Lory (*Lorius domicella*) from Moluccas, presented by Mr. T. P. Medley; a Mexican Guan (*Penelope purpurascens*) from Central America, presented by Mr. A. Warrington; two Gordon's Terrapins (*Platemys gordoni*) from Trinidad, presented by Mr. Devonish; a Tiger (*Felis tigris*) from India, a White-thighed Colobus (*Colobus bicolor*) from W. Africa, a West Indian Agonti (*Dasyprocta antillensis*) from St. Vincent, deposited; a Blotched Genet (*Genetta tigrina*), and two Crested Pigeons (*Ocyphaps lophotes*) bred in the Gardens.

## SCIENTIFIC SERIALS

The *Naturforscher* for July contains the following among other papers:—On the distribution of land and water in Northern Europe during the ice-period, by K. Pettersen.—On the diffusion of gases through thin layers of liquid, by Franz Exner.—On Helmholtz's theory of vowels, by E. von Quanten.—On the influence of the surface of di-electric bodies upon their action at distances, by Romich and Fajdiga.—On electrodes which cannot be polarised, by A. Oberbeck.—On the changes of colour in an alcoholic solution of cyanine, by El. Borscow. Cyanine is the blue colouring matter of the flowers of *Ajuga reptans* and *A. pyramidalis*.—On the determination of alcohol in wine, by M. Malligand.—On the action of a weak acid upon the salts of a stronger, by H. Hübner and H. Wiesinger.—On the influence of the season upon the skin of embryos, by Herr Dönhof.—On the action of electricity of high tension upon liquids, by G. Planté.—On the motion of the imbibition water in wood and in the vegetable cell, by Julius Wiesner.—On a simple means to find the poles of a rod magnet, by F. Müller.—On the analysis of Japanese bronzes, by E. J. Maumené.—On the nutrition of the animal body by peptone, by A. Gyergyai and P. Plosz.—On the conducting of electricity by flames, by F. Braun.—On the fauna of the Caspian Sea, by O. Grimm.—On the action of lime upon the germinating process of *Phaseolus multiflorus*, by J. Böhm.—The solubility of sodic nitrate and its hydrate, by A. Ditte.—The electric conduction resistance of air, by A. Oberbeck.—Influence of chlorine upon the nutrition of plants, by W. Knop.—On some experiments with disinfectants, by Herr Erismann.—Distinction between chemical and physiological ferments, by A. Müntz.—On the time of the disappearance of the ancient Fauna from the Island of Rodriguez, by A. Milne-Edwards.—Application of the tuning-fork to electric telegraphs, by P. La Cour.—On the climate at the Lower Jenissei, by W. Köppen.—Temperatures and specific gravity of the water of the German Ocean, by H. A. Meyer.—On the diffusion of moist towards dry air, by L. Dufour.—On the condensation of water in the soil, by A. Mayer.—What influences determine the sex of the hemp plants? by Fr. Haberlandt.

*Transactions of the Academy of Science of St. Louis* (*U.S.*), vol. iii. No. 2.—This part contains the following papers:—By Dr. C. V. Riley: "Hackberry Butterflies, Description of the early stages of *Apatura lycaon*, Fabr., and *Apatura herse*, Fabr., with remarks on their Synonymy;" "On the Oviposition of the Yucca Moth;" "Description of two new Subterranean Mites;" "Descriptions and Natural History of two Insects which brave the dangers of *Sarracenia variolaris*;" "Description of two new Moths." "Notes on the genus Yucca," by G. Engelmann; "On the Well at the Insane Asylum, St. Louis County," an account of a geological section, by G. C. Broadhead, who also contributes a paper "On the occurrence of bitumen in Missouri;" "Results of Investigations of Indian Mounds," by J. R. Gage; "Catalogue of Earthquakes in 1872-3," by R. Hayes; "On the Forms and Origin of the Lead and Zinc Deposits of S.W.

Missouri," by Dr. A. Schmidt; "On the *Terebratula mormonii*," by Jules Marcou; "On Climatic Changes in Illinois—its Causes," by A. Sawyer.

*Annali di Chimica applicata alla Medicina*, July.—The more important papers in this part are:—On some preparations from *Eucalyptus globulus* and *E. amygdalinus*, by G. Righini.—On soluble phosphate of lime, or hydrochloro-phosphate of lime, by G. Tarantino.—On a glycerine solution of salicylic acid, by Prof. S. Zinno.—On the hydrate of croton-chloral, by Dr. Weill.—On the aqueous solution of nitrous oxide, by Prof. Ritter.—On veratrine, by Lepage.—On the ozonisation of the air in unhealthy rooms, by Dr. Leuder.—On a green colour free from poison, by Prof. Casali.—On the function of wine in nutrition, by Bouchardat.—On diphtheria, by Dr. G. Tamborlini.—On a remedy against hydrophobia, by Jitzki.—On the reactions of cod-liver oil, by Buchheim.—On mineral waters in their relation to chronic diseases, by Durand Fardel.

## *SOCIETIES AND ACADEMIES*

### Vienna

**Imperial Academy of Sciences**, June 10.—On some mechanical effects of the electric spark, by E. Mach.—On the different solubility of different planes of the same crystal, and the connection of this phenomenon with some general principles of science, by Prof. Pfaundler.—On the boiling points of chloride of calcium solutions of different concentration, by the same.—On the latent melting heat of sulphuric bihydrate, by the same.—On the Pyrrhulina species of the Amazon River, and on a new Bryconops species, by Dr. F. Steindachner.—On the pretended dependence of the wave-lengths from the intensity of light, by Prof. F. Lippich.—Determination of the orbit of planet (100) Hecate, by Dr. J. E. Stark.—On the theory of the functions of three variables, by Prof. M. Allé.—On a new remedy against Phylloxera (ethylsulphocarbonate of potash), by Dr. Ph. Zoeller and Dr. E. A. Grete.—Dr. L. Löwy recommends salicylic acid for the same purpose.—Further researches on the molecular theory, by Dr. A. Handl.—On the determination of the mechanical equivalent of heat, by J. Puluj.

June 17.—Ichthyological researches, by Dr. Steindachner.—On some determined integrals, by Prof. L. Gegenbaur.—On the earthquake observed on June 12 in the vicinity of Vienna, by Prof. E. Suess.—On the conducting of heat by gases, by Prof. Stefan.—Meteorological observations made at Hohe Warte, near Vienna.

June 24.—On the determination of nitrogen in albuminates, by Dr. L. Liebermann.—On the quantities of nitrogen and albumen present in human and in cows' milk, by the same.—On the origin of the acacia gum, by Dr. J. Möller.—On alluvial territories, by Dr. A. Boué.—On a new method to use Böttger's sugar test, by Prof. Brücke.—On the action of chlorine upon solutions of sodic citraconate and sodic mesaconate, by Th. Morawski.—On the tannic acids of the oak, by Dr. J. Oser.—On the manner in which guano is formed, by A. Habel.

July 8.—On a new form of Fresnel-Arago's interference experiments with polarised light, by E. Mach and W. Rosicky.—On acoustic attraction and repulsion, by Dr. V. Dvorak.—On the elastic after-effects from torsion of steel wires, by Dr. J. Finger.—Some experiments on the magnetic effects of rotating conductors, by Dr. J. Odstrcil.—On the conversion of acids of the series $C_nH_{2n-2}O_2$ into such of the series $C_nH_{2n}O_2$, by Dr. G. Goldschmidt.—Theoretical kinematics, by F. Reuleaux.—On the influence of pressure and draught on the thermal coefficients of the expansion of bodies, and on the relative behaviour of water and caoutchouc, by C. Puschl.—On gentisine, by Herr Hlasiwetz and Dr. Habermann.—On glutaminic acid, by Dr. Habermann.—On the structure of the spinal ganglia, by Herr Holl.—On the Adriatic Annelida, by Dr. E. von Marenzeller.—Researches on artificial misformations in hens' eggs, by Dr. Szymkievicz.

### Paris

**Academy of Sciences**, Aug. 16.—M. Frémy in the chair.—The following papers were read:—Meridian observations of the minor planets, made at Greenwich Observatory (transmitted by the Astronomer Royal) and at Paris Observatory during the second trimester of the year 1875, communicated by M. Leverrier; the planets observed were Nos. 7, 25, 8, 82, 93, 53, 54, 108, 55, 23, 110, 72, 62, 68, 74, 128, 113, 26, 45, 29, 88, and 64.—Remarks by M. Leverrier on the lately discovered planets 144 and 145.—On the structure of the ovum and of the seed of Cycadeæ, as compared with that of different fossil grains of coal deposits, by M. Ad. Brogniart.—Some remarks by M. Chevreul on a historical note relating to J. B. van Helmont, *àpropos* of the definition and of the theory of a flame by M. Melsens.—Ninth note on the electric conductibility of bodies which are only moderate conductors, and on the electric polarisation of minerals, by Th. du Moncel.—A note by M. F. Tisserand, on the observations of shooting stars on Aug. 9th, 10th, and 11th last.—On the reducing action of hydriodic acid at low temperatures upon ethers proper and on mixed ethers, by R. D. Silva.—Synthetical researches on the uric group, by M. E. Grimaux (second paper).—A note by M. Cornu, on the presence of Phylloxera galls, spontaneously developed on European vines.—M. Vinot then presented an instrument to the Academy, which he calls *sideroscope* and, which enables any person, however ignorant of astronomy, to find easily all constellations and the principal stars.—Note on a new method of giving proper signals at sea, by M. Trève.—On the action of copper and its derivatives on the animal organism, by MM. Ducom and Burg.—On an acid obtained from wine, which turns the plane of polarisation to the right, by M. Maumené.—Analysis of the gases given off by the soil on the island of St. Paul, by Ch. Velain.—On Blaen's globes, and on a discovery made by the same in 1600, of a variable star in the constellation of Cygnus, by M. Baudet.—Fourth note by M. J. M. Gaugain on the process of magnetisation.—On some new singing flames, by M. C. Decharme.—Researches on tempered glass, by MM. V. de Luynes and Ch. Feil.—On some double metallic sulphocarbonates, by M. A. Mermet.—On a proper reaction by which to recognise sulphocarbonates in solution, by the same.—On the active part in the seeds of pumpkins as employed as a remedy against tape-worms, by M. E. Heckel.—On the post-tertiary fauna of the caves of Baoussé Roussé in Italy, commonly called grottoes of Mentone, by M. E. Rivière.

## BOOKS AND PAMPHLETS RECEIVED

British.—A Yachting Cruise in the South Seas: C. F. Wood (H. S. King and Co.)—Transactions of the Watford Natural History Society, Vol. i. Part 1.—Rotomahana, and the Boiling Springs of New Zealand, by D. L. Mundy and Ferd. von Hochstetter (Low and Marston).—Journal of the Anthropological Institute, Vol. iv. Part 2; Vol. v. Part 1.—Snicland, or Iceland; its Jokulls and Fjalls: W. L. Watts (Longmans).—Protection of Life and Property from Lightning: W. McGregor (Bedford, Robinson).—Game Preserves and Bird Preservers: G. F. Morant (Longmans).—Geology: James Geikie (Chambers).—Magnetism and Electricity: John Cook (Chambers).—Chemistry: A. Crum-Brown (Chambers).—Astronomy: A. Findlater. (Chambers).—On the Relation between Diabetes and Food: Dr. Donkin (Smith, Elder and Co.)—Impressions of Madeira: Wm. Longman (Longmans).—Light as a Motive Power: Lieut. R. H. Armet, Vol. i. (Trübner).—Rambles in Search of Shells: J. E. Harting (Van Voorst).—Syllabus of Plane Geometry (Macmillan and Co.)—Instructions in the Use of Meteorological Instruments: Robt. H. Scott, M.A., F.R.S. (Official).—Quarterly Weather Report of the Meteorological Office, Part 4, 1873 (Official).—Second Report on the Sanitary Condition of Oxfordshire: G. W. Child (Longmans).

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